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A paper read at the 163d meeting of the American Institute of Electrical Engineers, New York and Chicago, March 28, 1902.

THE TELEPHONIC STATUS QUO.

BY ARTHUR VAUGHAN ABBOTT

It is difficult to estimate the present telephonic situation without the recitation of a little history that may appear quite trite to many.

The introduction of the telephone dates from 1876, when, at the Centennial Exposition, the Bell magneto instrument was publicly exhibited. Almost immediately the patents covering this and subsequent kindred inventions, afterward construed to cover all feasible methods for the electrical transmission of speech, passed under the control of an association, which under one corporate name after another, and in combination with its various operating and manufacturing affiliations, has been popularly collectively known as the Bell Telephone Company. The a method of developing telephonic business consisted in forming manufacturing company whose function was that of creating the necessary apparatus, and a large number of operating companies, one in each particular territory, to absorb and use, under license, this apparatus in serving the public. In all the subsidiary companies the parent organization took an active part, always retaining a controlling interest, so that the entire telephonic business of this country was, during the lifetime of the fundamental patents, to all intents and purposes, that of a single management.

The inception and perpetuation of an enterprise to operate over this entire continent, necessitating business relations of the most heterogeneous character, required the exercise of the keenest skill and shrewdness in the manipulation of men, and thus acquired the greatest advantages in uniformity, strength

and coherence. Quite possibly, under any other form of organization, American telephonic development would be far behind what it is to-day, for it cannot for a moment be denied that the Bell system is a most magnificent masterpiece, both of business and technical engineering.

But with all these virtues some faults appeared. Seemingly a policy of secrecy prevailed. Telephonic conventions, initiated in the earlier days, were abandoned, or held at the rarest intervals; that freedom of speech so dear to the American mind, the exercise of which developed the later inventions of the electric light and the electric railway in a shorter period of time to a wider degree, was frowned upon even to the extent of non-technical publications. For the writer well remembers, after a popular magazine article, his general manager intimating, that good telephonists should, like small boys, be seen and not heard. Search as one may, where in our transactions will one find a paper from a professional telephonist, save Mr. Carty's classic and ancient (though classic in spite of its age) exposition of electrostatic induction? The manufacture of apparatus, particularly of transmitters and receivers, was sedulously guarded and the magneto bell, the receiver and solid-back transmitter stand to-day, after one or two decades of experience, unchanged and unimproved.

Nor was technical reticence, and consequently impeded progress the only consequence. Gradually, in the public mind, arose an undefined feeling that something was wrong with the telephonic "*quid pro quo*." Alleged extortionate charges, coupled with complaints of poor service were whispered about. Legislative and aldermanic investigating committees were appointed that resembled the fabled characteristics of the month of March, for they went to work like lions, only in due process of time to subside into the most lamb-like serenity. People saw only an insignificant bit of apparatus which their common sense told them could be made for a dozen dollars, for the annual use of which a charge of from $50 to $250 was made. Small wonder, then, in view of this insufficient evidence, that on the expiration of the fundamental patents, there were hosts of enterprising electricians, many of them of the locksmith and bell-hanger type, who were ready to flood the market with telephonic apparatus of all kinds, good, bad and indifferent; or that there was a public trained and educated to embrace any telephonic relief from the real or fancied oppression of a so-called

grasping monopoly. It is no part of the present paper to examine into the validity of the grounds for this state of public sentiment. But it exists, deeply and strongly rooted in the public mind, fixed therein by nearly a score of years of most unfortunate training; so firmly seated that in some cases independent exchanges, charging regular rates, have flourished and grown fat in the face of absolutely free service offered by the older company, in the hopes of crushing by the superior endurance of a powerful backing, its younger and seemingly weak rivals. So strong is this sentiment that to-day, though the Bell companies are nearly a quarter of a century old, and the independent companies barely six years, the field is quite evenly divided between them as is shown by the statistics in Table I.

TABLE I.

ITEM.	BELL EXCHANGES.	INDEPENDENT EXCHANGES.
Invested capital	$320,000,000.00	$150,000,000.00
Number of exchanges	1,500	2,811
Sub-stations	1,080,000	1,198,000

During the past year about $18,750,000 has been spent on telephone apparatus; of which about 40 per cent. is credited to the independent interests, and in this field 415 new independent telephone companies have been floated.

So far as apparatus is involved, there are to-day a number of firms that can, and regularly do, produce transmitters and receivers whose clearness and volume of articulation cannot for a moment be considered to be inferior to those manufactured by the older corporation. There are at least two companies that are prepared to, and do manufacture as broad and variegated a line of switchboard apparatus, are well equipped, do as good work, attain similar results, and are supplied with electrical talent equal to that of the Bell Company's. So, it is possible to-day for anyone to build a first-class telephone exchange, and with good care, shrewd and expert management, to give service that cannot be excelled at the lowest possible price. Such, I say, is possible, but, unfortunately, it is rarely done. On the contrary, a very erroneous idea prevails in the mind of most of the independent companies as to the requirements and limitations of telephony. A large portion of those interested therein seem to have been bitten by a kind of telephonic tarantula until they feel that a telephone exchange is a sort of Golconda. Put it in and it will run itself, rolling in dividends in a way to make the goose

which laid the golden egg blush for incapacity. According to their doctrine, all one has to do is to put in a telephone (any kind of a telephone) build a line (any kind of a line), set up a switchboard (any kind of a switchboard), go away and leave it to its own devices, returning once a year to collect the dividends. For instance, the general manager of a 5,000 line independent exchange recently remarked in answer to a question as to cost of maintenance, "why, we don't have any maintenance, we have a new plant." And another man, president of more than one telephone company, laughed me to scorn when I advised him to allow $2 per sub-station per year for maintenance expense, averring that ten cents per year was amply sufficient for the purpose.

Another and more vicious result of such misconception. is the way in which new telephone companies are floated. Half a dozen of the prominent citizens of some town conceive the idea of establishing a telephone exchange; an ordinance is rushed through the City Council of which one or more of the "prominent citizens" are members, a company is formed, enough stock subscription raised to pay current office expenses, and the labor of erecting a few miles of wire. The switchboard and a lot of material is purchased on three months, six months or a year's time, a few subscribers connected up, and lo! a full-fledged telephone plant is in existence, which the incorporators now proceed to mortgage to some confiding trust company, using a good block of stock as tempting bonus, securing to themselves a nice profit, and incidently getting funds to pay for the switchboard, and other material previously purchased on credit. How mistaken are these ideas, the first financial cold breeze that blows over this country will surely demonstrate. Indeed, the preliminary puff is already felt as is testified by the present lamentable financial condition in Cleveland, for if ever the true epitaph is written over the unfortunate Everett-Moore syndicate it will read, "Died of too much telephone."

Such a condition of affairs is partly due to unprecedented prosperity in America, but it must not be forgotten that both prosperity and poverty progress in cycles. We are now about at the crest of the present prosperity wave, and in the flush of plenty and success, men grow careless and plunge wildly into all sorts of enterprises. Oh! for some Joseph that could rend aside the veil, and show the lean and hungry years of the future waiting to devour the sleek and well fed ones of the present. But, more

than all, the public has been educated to regard the telephone from an entirely false standpoint, both as regards the instrument itself, and the annual charge for its use. I do not believe that one per cent. of the population of New York City have ever seen a switchboard, or that one-tenth per cent. have the slightest conception of the maze of circuits that traverse the streets. How many of us, electrical engineers though we are, and so presumably familiar with at least the rudiments of telephony, know anything of the tortuous path traversed by the messages we send a dozen times a day from our desks? By the formerly universal flat rate system, a certain charge per annum was made for each instrument, and this method indissolubly linked the telephone instrument with the price charged. This is a false unit, and the erroneous impression thus created in the public mind will take years of sorrowful and patient eradication. It is not the instrument, but telephonic service that the subscribers pay for; not the transmitter and receiver that stand on the desk only, but the conduits, cables, switchboard, trunk line plant, the operators who patiently, night and day, await an instantaneous summons, and all the other complicated paraphernalia that complete an extensive business organization. All these and more are included in the necessary cost of service, and if only the cloud of mystery that has for so long obscured telephonic practice were dispelled, and the public taken fully into the confidence of the operating company, much of the present friction would be obviated. People would gain not only true appreciation of the service performed for them, and so be more tolerant of tariffs, but would also acquire such a knowledge of the telephonic *modus operandi* as vastly to increase the efficiency of every telephone plant. In this respect, the independent companies are setting an admirable example. Frequent conventions take place at which free and open discussions of all subjects of interest are held, to which all, whether friend or foe, are equally and cordially welcomed. Each week the technical papers of the land chronicle all items of progress in so free and full a manner as to display the most striking contrast to the years of grim and forbidding silence maintained by the older organization.

There appear to be five results that are certain to follow:

First: Many of the present organizations lacking in experience and strength, located in unpromising fields will go down with the first monetary stringency, throwing by their ruin considerable disfavor on the financial aspect of telephony.

SECOND: The remaining independent companies will be forced to adjust their rates until such a point is reached as to enable them to become investments of reasonable earning power, and to this end only the most carefully designed, best constructed and most shrewdly managed plants can possibly survive.

THIRD: The rates of the Bell companies must fall until both the Bell and the independent companies meet at a common level and thereafter, so far as the public is concerned, it matters little which gives service.

FOURTH: The independent companies are weak in their lack of coherence, feeble in possessing but few exchanges in the larger towns and almost none in the great cities, and powerless in the toll and long distance field. New York is the keystone of the telephonic arch, and when that city is captured by an independent company, the battle will be more than half won, but judging from recent developments in this direction, that time is still in the somewhat far distant future.

FIFTH: An extensive and far reaching tariff revision is the vital question of the present. If the Bell companies heed the tendencies of the times, they may yet not only retain, but revive a fast diminishing supremacy. Failing in this respect, they will be forced to meet this just demand, either by the struggle for existence in the face of fiercest competition; or by the pressure of ordinance regulations, as has recently been witnessed in Chicago; or by such legislative action as will declare all telephone companies to be common carriers, and compel each to handle and transmit to its own subscribers any messages delivered by the other.

In possession of a country of unbounded resources, the American public is of all peoples the easiest and most tolerant to deal with. It has made money and it expects and wants everyone else to do likewise. It is good-natured and somewhat careless as to what it pays, provided good goods are returned, and charges that are equitable and just to all are made. But woe betide those who attempt to get something for nothing, or to discriminate unfavorably between different portions of society. Their fate is certain.

It is this innate feeling that has instituted the revolt against the flat rate system. One does not contract by the year with the milkman for all the milk the family can drink, nor with the baker or butcher for all bread or meat, nor with the gas company for all the gas one wishes to burn. The electric light people

even go so far as to install a demand meter, scaling bills not only upon the quantity of electricity used, but considering also the time at which it is asked for. To charge a subscriber who makes 100 messages per day the same rate as one who makes 10 is obviously unfair, and driven from the illogical flat rate system, the plan of an initial charge, plus a message rate for all calls beyond a certain annual number, has gained considerable currency. That this is an improvement and more just than the former method cannot be gainsaid, but even this scheme contains large elements of manifest injustice, for the message is no more the true unit of charge than going to a livery stable and hiring a carriage to take a drive would be a fair basis for the liveryman, for one customer might be gone an hour and another all day. The average length of telephonic conversations is about two minutes, but averages are dangerous. In one case under the personal observation of the writer, a young bride on her return from the honeymoon kept the line leading to her mother's house busy for several consecutive days for more than 40 minutes at a time. Query: shall the bride be charged ten cents for her call and you the same price for a two-minute conversation? No; the message rate system, while approximating more closely to the truth than the flat rate, is still on a false basis and should be corrected.

In giving service, telephone companies do three entirely separate and independent things which are incommensurable with each other, all of which every just and equitable tariff must recognize and express.

First: The telephone company supplies and maintains a certain amount of apparatus necessary to connect each subscriber with the central office. This apparatus must be furnished and cared for whether used or not, merely to give the subscribers an opportunity to call. The quantity and quality of this apparatus does not vary with the load, being the same whether the instrument is used once a year or 100 times a day. A flat rate annual tariff sufficient to pay interest, depreciation and maintenance on this portion of the plant is fair and just, and by recognizing varying lengths of subscribers' lines, this charge may be made exactly proportional to the requirements of each station.

Second: The telephone company must maintain a corps of operators to answer subscribers' calls and to perform the necessary avocations of connecting subscribers together. This

TABLE II.—General Telephone Statistics.

	Name of City.	Population.	No. of Telephones.	Per cent. of Telephones.	WIRE MILES. Underground.	Aerial.	Total.	Per Telephone.	TARIFF. Flat Rates. Business Telephones. 1 Party	2 Party	4 Party	Multi Party	Residence Telephones. 1 Party	2 Party	4 Party	Multi Party	Measured Service. Business Telephones. 1 Party	2 Party	4 Party	Multi Party	Excess Calls.	Com. Box.	Residence Telephones. 1 Party	2 Party	4 Party	Multi Party	Excess Calls.	Com. Box.
									$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$
B	Baltimore	507,000	6,300	1.25					125	100			100	78	60						.06		1000 c	1000 c	1000 c			
																							72	62	48		.04	
I	"	"	6,000	1.25	1,140	757	1,897	.3	48	42	32		36	30	24						.05					365 c		
																										18.25	.05	.05
B	Boston	560,892	23,106	4.1	47,600	7,400	54,400	2.3	262	141			116	102			1000 c	1000 c	1000 c				1000 c	1000 c	1000 c			
																	90	75	66		.04		90	75	60		.04	
B	Buffalo	352,219	9,449	2.7	6,830	5,475	12,305	1.3									1000 c						1000 c					
																	70				.06		52					
B	Chicago	1,698,575	37,969	2.2	108,633	33,190	141,823	3.8	175				100	75	60		1000 c	1460 c		1000 c			1000 c	1460 c	1000 c	365 c		
																	92	73		48	.05	.05	92	73	48	18.25	.05	.05
B	Cleveland	381,000	13,744	3.5	28,623	13,119	41,742	3.8	84	72			60	48			1000 c	1000 c	1000 c									
I	"	"	9,000	2.4	9,000	4,500	13,500	1.4	48				36				60	48	36		.03	.05						.05
B	Columbus	125,560	8,500	6.8	7,964	8,164	16,128	1.9	40				24									.05						.05
B	Indianapolis	169,000	4,537	2.7	9,600	12,500	22,100	4.8	40				24															
B	Kansas City	163,000	7,200	4.4	6,500	7,500	14,000	1.15	96	75	52		72	60	42		1000 c											
																	72				.05	.05						.05
B	Louisville	204,731	6,624	3.2					96	78	48	36	60	48	30	18	1000 c											
I	"	"	5,000	2.5					48				36				74				.05						.015	
B	Minneapolis	202,000	9,025	4.5	11,859	7,655	19,514	2.15	84	72	54	18	60	48	36	18	1000 c	1000 c	1000 c				1000 c					
																	72	62	48		.03		60				.03	
B	Milwaukee	285,000	8,900	3.1	12,529	5,559	18,088	2.0	96	72	60		60	48	36		1000 c	1300 c	1000 c				1000 c	1000 c				
																	68	60	50		.02	.05	48	36			.02	.05
B	Nashville	86,000	3,498	4.0		1,030		.29	84	48	36		54	36	24		1000 c						1000 c					
B	New Orleans	287,000	6,000	2.1					120				60				41				.05		33				.05	
B	New York	1,850,000	63,975	3.5	152,807	2,455	155,262	2.25	240								1000 c	1000 c					1000 c	1000 c	1000 c			
																	99	87			.08		90	87	78		.07	
B	Omaha	102,000	3,851	3.7	3,571	1,758	5,326	1.4	90	72	48	24	66	48	36		1000 c						1000 c					
																	72				.04		72				.04	
B	Philadelphia	1,400,000	23,438	1.7	72,618	7,808	80,426	3.5	160								1000 c	1000 c					1000 c	1000 c	400			
I	"	"							80	52			48	36			78	66			.05		69	60	36		.03	
B	Pittsburg	451,512	11,086	2.5	22,388	13,227	35,615	3.0	125	100	80		100	80	60		1000 c						1000 c					
																	70				.04		70				.04	
B	Rochester	162,608	4,200	2.6	11,550	800	12,350	3.0	94	64			36	24			1000 c						1000 c					
I	"	"	4,200	2.6	3,324	2,011	5,335	1.25	48				30	24			70				.06		36				.04	
B	San Francisco	342,000	29,735	8.5	23,365	7,100	40,665	1.4					66	60			1000 c	1000 c		365 c						365 c		
																	140	104		18.25	.05					18.25	.05	
B	St. Louis	575,238	7,851	1.4	8,465	11,940	20,405	2.6	150	100			72	48			1000 c	1000 c					1000 c	1000 c				
																	69	57			.04		57	5			.04	
B	St. Paul	166,000	5,715	3.5	7,356	3,297	10,653	1.9	84	72	54	18	60	48	36	18	1000 c											
I	"	"	1,314	.8					46				30				60				.03						.03	

NOTE.—This table is compiled from various sources, and is believed to be fairly accurate within about six months.

expense is directly and only proportional to the number of times each station calls.

THIRD: During each conversation, battery is supplied to the subscribers' station for talking, cords, plugs, trunk lines and other common apparatus is in use, the amount and cost of which is proportional to the length of time of conversation.

Therefore, any telephone tariff to be fair to all, must recognize these three factors, and in so far as any one is omitted, and a blanket charge substituted therefor, injustice will be done, depending on how far the service rendered to a particular station departs from the general average.

To perceive the bearing of this proposition, consider for a moment the cost of installation and service. According to previous telephonic policy, the ratio of the number of telephones to population is very low, as is shown in Table II. Consequently, the installation cost per station has been high. In large cities this has varied from $150 to $250 per station. In medium cities, of say 200,000 population or so, from $90 to $125, while even in the smallest towns it is rare to find a cost of less than $50 per station. Of the installation cost, from $10 to $25 is required at the sub-station, depending upon the character and difficulty of wiring. From $15 to $50 for the switchboard, varying with the type of board, size of multiple and percentage of trunking, while the wire plant has absorbed the balance: but if by a more liberal policy the use of the telephone could be so stimulated as to raise the population ratio, to say 15 per cent., it would be possible, even in such a city as New York, to install a telephone plant at a cost not to exceed $60 per sub-station, as is shown in Table III.

TABLE III.

Probable installation cost per station of a telephone plant, sufficient to serve 15 per cent. of population.

ITEM.	COST.
Sub-station Apparatus	$15.00
Wire Plant, Subscribers' Lines	14.00
Wire Plant, Trunk Lines	7.00
Switchboard Apparatus, Subscribers' Lines	12.00
Switchboard Apparatus, Trunk Lines	6.00
Total	$54.00

Assume now that an installation charge of $15 per year per sub-station were made against each one-party line to cover interest,

depreciation and maintenance, $10 per year per station each against two-party line and $8 per year per station against each four-party line, and that a charge of one cent was made for each time the central office was called up and one-half cent for each minute of actual time that the telephone was in use. Large business houses and the best class of residences would take one-party lines. Smaller business houses and medium residences two-party lines, while the bulk of subscribers would use four-party lines; all of these being arranged with selective signals and lock-outs to secure the best quality of service. Simply to illustrate the effect of this system of tariff, assume one-party lines to average ten calls per day, two-party lines seven and four-party lines three. Under these circumstances, one-party lines must bear a tariff of $75 per year; two-party lines $52 and four-party lines $23. According to this suggestion, the annual cost of maintenance and depreciation on plant would be cared for by the annual flat rate charge, which, for this purpose, is sufficient in a properly installed and maintained plant. The receipts from traffic would average $20 per thousand calls, while the actual expense should not be over $7 per thousand calls. The difference of $13 would be ample to pay reasonable general expenses and dividends. At each sub-station, a meter would be installed, carrying two dials, one showing how many times the exchange was called, and the other the total time expended in the use of the telephone. This meter should be in plain sight of the subscriber, so that he, at any time, could check the readings with his own watch. Such a device could be made and installed at an expense not to exceed $3 per station. Each station would be charged for exactly the service rendered, and it would be optional with all to regulate charges to suit their wishes.

It is probably an impossibility to make any one method of charging absolutely universal, any more than it is feasible to crowd all passengers on a railway into one car. There must be Pullmans, coaches and emigrant cars. So every telephone company must probably supply a few flat rate instruments, many meter rates and some coin boxes. "*Chacun à son goût*," but the main idea is that of producing a rate that will be absolutely just, and be capable of so stimulating telephonic business as to place an instrument in every house. Each community contains some chronic objectors whom it is impossible to satisfy, but setting such aside, it seems that a scheme of this general nature would go far toward smoothing out the existing friction between the operating companies and the public.

But with this discussion of the commercial aspect, the engineering side must not be entirely forgotten. Two very curious tendencies are observable. Among the older companies and the most advanced of the independents, those to whom experience has read some bitter lessons, there is a very strong inclination to design plants with the utmost care and skill, using the widest and best experience for the purpose, and foreseeing the future as far as possible. This is in marked contrast to the practice of a decade ago, when telephone plants, like "Topsy," simply grew, and in many respects were not unlike the dark heroine of Uncle Tom. But with the newer and less experienced of the independents, there is a most conspicuous absence of design. Because some farmer has talked half a dozen miles over barbed wire fences, a lo tof little telephone companies have immediately built toll lines of No. 10 or even No. 14 iron wire, on poles about as large as a walking stick, with grounded lines, through trolley towns, and wonder why their subscribers complain of poor service, or that their lines go down with the first snow.

Conduit construction has settled into pretty well recognized channels, involving chiefly the use of vitrified clay pipe, particularly the multiple duct forms. Periodically, a new and improved form of duct material appears destined to supersede all others, but I notice the tile men serenely go their way, and their output to-day is larger than ever.

The construction of aerial lines is rapidly becoming systemized and proceeding under standard specifications, the tendency of which is to build the lines much more efficiently and much more solidly than in the past, and to restrict the use of open wires to three or four cross arms.

There is a notable tendency to increase the size of cable. Formerly 120 pair was standard for underground work and 25 for aerial, but at present 200 pair is becoming almost universal, and even 400 pair has entered the field underground; while aerial cable has grown so that 150 pair is not unknown. For trunk lines and toll work, large conductor, low capacity cables are to the front, even to the extent of using No. 16, No. 14 or even No. 12 wire, with capacity of from .06 to .05 m. f. per mile. In switchboard practice, the common battery automatic signal board is rapidly expelling all other forms and soon will apparently reign supreme, for at present there is not a shadow of a rival looming on the telephonic horizon to dispute its supremacy. While switchboards of this type are a vast improvement

over those of older construction, they still leave much to be desired, and the entire telephonic fraternity awaits with open arms the coming of the perfect switchboard. There are many who believe that a purely automatic board will offer the desired solution, but during the past decade the progress in this direction has been almost infinitesimal. A central office seems to be one of those things that need the human element, and cannot be made purely mechanical. Possibly the recently invented Faller mechanical operator may form at least a partial solution.

For the sub-station there is no progress to report. The transmitter, receiver and magneto have remained *in statu quo* for ten years, save that each manufacturer dresses his apparatus in a newer and possibly more fanciful design. This is strange when is considered that actual telephonic efficiency is less than two per cent., and that a very slight improvement in this direction would be hailed with delight by all, particularly by those who do much toll work. Part of the difficulty lies in the electrical characteristics of the line, and for this Dr. Pupin's epoch-making discovery is supposed to be a remedy, but as yet results from practical experience therewith have not been reported.

In the light of the present, what is the earnest of the future? Despite the hints of our friends of the Hertzian waves, there is nothing at present to suggest any radical discovery in the telephonic field. On the other hand, the art is gradually settling down to that inevitable and comfortable basis wherein sound financial judgment as to the expediency of a telephone plant, skillful engineering in design, the best possible construction, good business management in operation, fairness in the tariff and in the treatment of the subscriber, will be absolutely essential to produce a good balance sheet. Toward this haven strongly sets the current of popular opinion, aided by those who are most broad minded and liberal in the business. May the art safely reach this port, avoiding both the Scylla of a disastrous rate war and the Charybdis of financial wreck from rash, ill-advised investments, systems poorly constructed and operated.

A paper presented at the 163d Meeting of the American Institute of Electrical Engineers, New York and Chicago, March 28, 1902.

TELEPHONE RATES FROM AN ENGINEER'S VIEW-POINT.

BY FRANZ J. DOMMERQUE.

Reviewing the present method of charging for telephone service, it is found that previous to the independent movement, the Bell licensees had a free hand and were in a position to obtain the highest rates. With a competitor in the field charging lower rates, the old companies had to find some means to meet this competition and to retain at the same time the old revenues. Three methods of charging for service were introduced besides the old time flat rate; namely, measured service, pay stations and party line service. The introduction of these three additional kinds, however, deteriorated the service given to the public. The independent companies did not imitate the Bell licensees in their charges, but kept to the flat rate exclusively, distinguishing, however, between charges for business houses and for residences, thereby not impairing service. This seemed fair to all parties concerned, because the amount of work to be performed by an operating company justified a reduction in rates for residences, as the average number of calls per day from a residence subscriber is less than from a business subscriber and, consequently, the number of operators required for residence service is less than for business service. Experience quickly demonstrated that the arrangement for more than two parties on one line was not liked by the subscribers. Measured rate and pay-station service had the appearance of justice, as the subscriber paid for each call he made and thus could not find fault with the company. Naturally, he became careful in the use of his telephone, thereby reducing his number of calls to a minimum

and, to some extent, the company was the loser, as it had to provide a sufficiently large plant and count the number of calls, either by mechanical devices or by writing out tickets; the latter being probably the method most in vogue. The writing of tickets is cumbersome and reduces the efficiency of the operators, and besides, is apt to make the subscriber suspicious of over-charge, as the subscriber has no control over the operator. However, the public gained an advantage in not having to pay an exorbitant rate for a small number of calls, but the rate per call was still high, as the telephone company made the measured rate correspond to the decrease in the number of calls.

It is a well-known fact that the greater the plant, or rather, the more subscribers that are connected with one and the same exchange, the higher the rates. Seemingly the subscriber in a village has the advantage over the city subscriber. The rate in the village is, say one or two dollars a month, or from $12 to $24 a year, while the city man pays $50 or more. But the villager reaches for his $12 only, say 100 subscribers, and in order to reach as many subscribers as the city man does, he will have to talk to other villages and, perhaps, over his whole county and pay toll charges for the privilege. Thus, to compare the rates the number of people reached must be taken into consideration.

Service given by small units, as in the case of a village, is considered cheap, and many can afford a telephone in a village, that could not in a city. Should it not be possible to arrange city service on the principle of village service and give every subscriber a comparatively low rate without resorting to means that deteriorate service? One step in that direction has been made already by establishing so-called private branch exchanges. We find as an example, hotels with telephones in every room for the use of the guests, the guests not paying for such service as long as they do not call for a party outside of the hotel, a small charge being made as soon as connection through the telephone exchange is desired. Such small units could be established in a great many large buildings in our large cities; a still better field for same would be found in the residence districts of our cities; usually the wealthiest classes congregate in the best localities where real estate or rent is high. The less fortunate members of the community choose less expensive quarters and so on down the scale of means. Accordingly, there are villages, so to speak, of the aristocracy, villages of tradespeople and the workingmen's villages. In each of these villages a great number of telephone

calls would be for people of the same village, and a flat rate could be established for such local calls that should not be much higher than the rate of the country village, and whenever a call is made outside of the local district, a small charge could be made per call, just as the country villager pays a toll charge. This would, it is true, involve again the making out of tickets, but only to a limited extent and would not involve so much labor by far on the part of the operator as when a ticket had to be made out for each and every call in the whole exchange. In the center portion or business district of cities there will be one large office, or in very large cities, more than one, to which individual business telephones are connected. But the business man in a city transacts such an amount of business that a reasonably high charge for the unlimited use of his telephone would be, and in fact is, gladly paid as long as the service is good. However, here too, a sub-division could be made by the use of two-party line service, which is not objectionable, as it does not deteriorate the service in general, being selective, i.e., either of the two parties may be called without annoying the other party by ringing, and two not very busy subscribers will not be inconvenienced by having to use one and the same line, for only in rare cases will both parties call just at the same time, which would happen frequently, however, with four or more parties on the same line. Thus, two business subscribers, each having not enough business to demand the exclusive use of one line, could share the line and thus reduce charges.

Such an arrangement as outlined above would tend toward large offices in the center of cities and smaller offices in the residence portions, and the engineer would have to lay out his plans on somewhat different lines from those which he is used to now.

Measured service introduces also a large amount of bookkeeping, which would be done away with if only flat rates were charged.

The method of charging and collecting monthly introduced by many independent companies is another hardship for the accounting department and should not be encouraged. A subscriber who wants service and wants it honestly cannot object to paying quarterly. A subscriber who delights in the one-sided economy of moving at the end of the month to unknown quarters, thereby cheating the telephone company and landlord alike out of a month's rent, is not a desirable customer in any sense.

The scheme of charging for telephone service would there-

fore be as follows: (1.) For the business portion of cities a flat rate to all busy subscribers, and a reduced flat rate to less busy subscribers using a two-party line. Pay stations, of course, cannot be dispensed with, but should only be used in certain quasi public places so as to give transients an opportunity of telephoning without having to intrude upon the regular subscriber. (2.) In the residence districts, flat rate for local calls with measured service for trunk calls. Here, also, two-party line service can be used probably to still better advantage than in the business portion and would double the capacity of a small residence district switchboard.

With more than one office in the business district of a very large city, the flat rate would be different in the various offices and would correspond with the average number of calls originating in the offices. A measured rate for trunk calls in addition to a flat rate for local calls should be made, I think, only outside of the business district where the total number of originating calls is low. This trunk charge would have another beneficial effect, as it would cut the calls in busy offices down to the lowest amount and thus help to keep down the trunk expense in such busy offices, which would not be the case, if the residence district subscriber, who usually is not pressed for time, could make as many trunk calls as he pleased under a flat rate.

One more word on the subject of measured rates. It is said that it is the fairest way to charge the public for what service it actually receives, and comparison is made with the charges for electric light and gas service. There is a fallacy in such comparison, because in electric light service as well as in gas service, reservoirs store the energy, i.e., accumulators in the case of electric light supply and gas tanks in the other case, take care of the peak or peaks of the load curve, while in a telephone plant we cannot store the energy developed by the operator, and must build our plant large enough for the highest peak of the load curve and therefore have, for say 22 hours of the day, a plant on our hands that is used at low efficiency. Thus the same switchboard equipment and a line has to be built for each and every subscriber whether he calls once or one hundred times a day. It is, therefore, no more than correct to charge a flat rate, allowing certain modifications, as the two-party line rate, and regulate the flat rate according to the plant and service required. Size of plant and number of operators being purely a function of the number of calls, the flat rate should be proportional to the number of calls.

There is another incongruity in the comparison. In electric light and gas meters the quantity of energy supplied or the time of duration of supply is measured, so that each consumer pays exactly for what he receives. In measuring telephone service, no account is taken of the time or duration of conversation, but the number of calls only is recorded. It is true that for local calls, i.e., for calls between subscribers connected to one and the same switchboard, duration of conversation does not noticeably influence the operating labor and thus would not enter into the question of charge, but for trunk calls, i.e., for calls that have to be transferred from one operator to the other, it is different. For local calls, one and the same subscriber is always connected to one end of his line and different subscribers may be switched onto his line; the subscriber may use his own line as long as he pleases, as nobody else would use it anyway. In the trunk line case, no subscriber is permanently connected to the trunk line and therefore subscribers may be switched onto either end of the trunk line, whenever the trunk line is free. Thus a trunk line (and toll and long distance lines the same) may be kept "loaded" all the time and it is clearly seen that the duration of conversation over trunk lines is an important factor and regulates the number of trunk lines, trunk sections, trunk operators and everything pertaining to it. This circumstance is well taken care of in toll and long distance charges. Therefore, a measured service for trunk calls seems justified and there might be also a time limit to trunk calls, but probably it would involve more labor on the part of the operator to take account of the time than the additional income would warrant; the case of toll and long distance lines is different, as great capital is invested in such lines, these being very long, while ordinary trunk lines are comparatively short.

So much about the kinds of rates. A few words now remain to be said as to the amount to be charged.

The easiest way to determine the charges, is to make them as high as the public will stand; but with competition in the field this method is excluded and the charges must necessarily settle down to a point where service can be given at a reasonable rate to the public, leaving a fair income to the operating company.

Under the Bell regime, the charges for telephone service are undoubtedly high enough to give a handsome profit to the operating company, while many independent companies have made

the mistake to start in with too low rates. In order to determine the correct rate that should be charged to assure the operating company a reasonable profit, all items that are involved in the annual expense should be closely calculated. The depreciation factor on the plant should not be taken too low, as there are so many unforeseen incidents such as blizzards menacing pole lines, new inventions making switchboards obsolete, etc., that may deplete the treasury in a short time. The allowance for depreciation should not be below ten per cent. on the switchboard; 15 per cent. on open wire pole lines; 4 per cent. on conduits; 12 per cent. on cables.

When figuring on the cost of operation, it must be taken into account that not only the salaries of operators working at the board, but also the salaries of chief operators, monitors, night operators, office managers, repair men, matron, janitor and messengers, as well as the salaries of the clerical force directly connected with the operating department, must be taken into consideration. The salaries of the officials of the company, as well as the taxes that have to be paid, are to be charged under the heading of fixed charges. A reasonable amount of rent must be charged, and in this point care should be taken not to make the figure too low, as it is often found afterwards that the rent to be paid for the best location of the office is high, because the owner of the property has found out how desirable his property is and charges accordingly.

In estimating upon the cost of the aerial and underground construction, a good many local circumstances have to be taken into consideration, as the formation of the soil, whether it is favorable or unfavorable for the setting of poles, etc. In the case of underground conduits there are obstructions to overcome, the streets in many cities being filled with all kinds of pipes so that it is very hard to lay additional conduit. I remember that in the city of Chicago, an amount of $1.20 per linear foot was added to the cost of the underground conduit in a certain street on this account.

As far as the maintenance of the plant is concerned, the figures should not be taken too low. Of course, on underground conduits the maintenance means very little, while on aerial lines it may be as high as $25 per subscriber per year.

It is impossible to give a general figure for all the items constituting the annual expense of the telephone plant, as size, as well as natural conditions of cities, differ. It is the work of

the engineer to determine in every case all the items and make an estimate which is not too low, but at the same time economical.

In many cities lately, the administration, in giving franchises to independent companies, has taken advantage and forced the new-comer to accept the most severe conditions, and even has gone so far as to fix the rates. If a city takes it on itself thus to restrain a company, it should have investigated closely the probable cost of giving service, and should have done this under the advice of a telephone engineer who is thoroughly familiar with laying out telephone plants in general and with the city under consideration in particular. If the city administration fixes the rates, it is no more than fair to demand that the city administration make public the estimate upon which it bases such rates as it has fixed, so that an opportunity may be given to the franchise-seeking company to point out in what particulars such an estimate may be unfair or even incorrect.

A paper presented at the 164th Meeting of the American Institute of Electrical Engineers, New York and Chicago, April 25, 1902.

POWER CONSUMPTION OF ELEVATORS OPERATED BY ALTERNATING AND DIRECT CURRENT MOTORS.

BY GEORGE F. SEVER.

The record of electrically operated elevators in New York City shows that there are approximately 3,000 operated by direct current motors, and 300 operated by alternating current motors. One reason why this disproportion exists is that the direct current motor has been available for a longer period than the alternating. Another is the uncertainty as to the amount of power necessary for each. If the consumption of power for one type of elevator makes its operation more expensive than another, but the use of this type overbalances any disadvantages possessed by one which consumes less power, then it will be the more desirable machine. Certainty of operation due to simple controlling devices, great overload capacity permitting the elevator to be operated under unusual conditions, are two important requirements. If the alternating current motor cannot fulfill these requirements economically, we find immediately another explanation for its small application as compared with the direct current motor. When the location of the apartment house or office building is such that it is not possible to secure direct current for the operation of electric elevators, it is of course necessary to use the alternating current. In some sections of the city it is at present impossible to obtain a direct current supply and the users of elevators have been of necessity compelled to install the alternating current system.

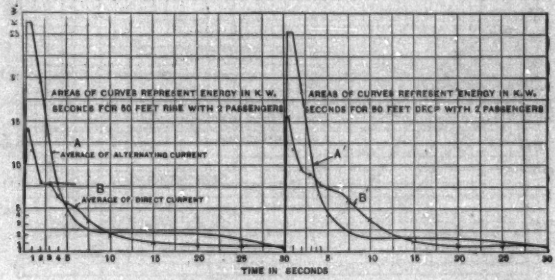
It was brought to the writer's attention that there was considerable difference of opinion as to the consumption of power for the two different types of electric elevator, one using alter-

TABLE I.

Test No.	Location.	Date installed.	Type of control.	Rise in feet.	Velocity. Designed	Velocity. Actual. Down	Velocity. Actual. Up	Duty in pounds.	Overweight in lbs.	Motor capacity and type.	Load.	Volts at line.	Current for starting.	Current for running.	Power in k. w. for starting.	Power in k. w. for running.	Power factor starting.	Power factor running.
1	Horace Mann School 120th St., N. Y.	June 29, 1901.	Magnet control, style P. A.	70′–1″	200′ per minute.	200′	200′	2500	900	120 volts, 175 amperes, 800 r.p.m.	2 people up. 2 " down. 3 " up. 3 " down. 10 " up. 10 " down. 23 " up. 23 " down.	110	141 144 140 145 150 140 199 145	15.4 77 85 87 80 20 150 —	15.5 15.8 15.4 15.9 16.5 15.4 19.8 15.4	1.71 8.63 2 75 7 3 8.8 2.2 16.5	Direct current.	
2	Mason & Hamlin, 136 5th Ave.	May, 1894.	Magnet control.	58′–3″	125′	125′	123′	1500	275	7 h.p., 220 volts, 1,000 r.p.m.	2 people up. 2 " down. 3 " up. 3 " down. 4 " up. 4 " down.	240	49 6 47.5 50 49 52 48	5.5 8 5 8.0 6.0 10.0 4.0	11.9 11.4 12.0 11.75 12.48 11.5	1.38 2.04 1. 92 1.044 2.4 0.96		
3	S. Stein & Co., 5th Ave. & 18th St.	Feb., 1902.	Direct-regulated control by hand.	——	—	—	—	1500	—	230 volts, 75 amp., 630 r.p.m.	2 people up. 2 " down. 7 " up. 7 " down. 14 " down.	240	74.8 77 72 66.5	21.6 32.5 43 10 12.5	17.95 18.5 10.3 17.3 15.97	5.18 7.3 2.4 3.0		
4	Transit Building, East 42d St.	Feb., 1901.	Magnet control, style 67.	121′–5″	300′	300′	300′	2000	500–600	220 volts, 100 amp., 800 r.p.m.	2 people up. 2 " down. 4 " up. 4 " down. 6 " up.	240	82 85 81.3 24 86	10.7 34 21.8 20	19.7 20.4 19.5 20.6	2.57 8.16 5.23 5.76 2.8		
5	Bryant Park Studio Building.	March, 1901.	Magnet control.	162′–10″	300′	300′	300′	1500	250	20 h.p., 230 volts, 800 r.p.m.	2 people up. 2 " down. 4 " up. 4 " down.	240	82 83 F3 2 81	29 22.6 36 18	19.7 19.9 20 19.45	6.97 5.43 8.65 4.32		
6	Altman Apartment, 923 West End Ave.	May, 1899.	None.	75′–6″	150′	156′	151′	1500	250	2-phase motor, 200 volt, 60 cycles.	2 people up. 2 " down.	200	170 186	18 36	30.5 34.7	1.42 2.5	.89 .92	.42 .34
7	Katahdin, 567 West 13th St.	Dec., 1899.	None.	74′	125′	129′	124′	1500	600	2-phase motor, 200 volt, 60 cycles.	2 people up. 2 " down.	200	150 150	20 6	25 24	1.3 0.5	.95 .91	.37 .43
8	Wharfedale, 606 W. 115th St.		None.	——	—	—	—	1500	—	2-phase motor, 200 volt, 60 cycles. Variable speed, no load speed, 900 r.p.m.	2 people up. 2 " down. 3 " up. 3 " down.	200	172 170 1 73 —	33 6 29 29.2 30	30.8 29.6 29.2 30.0	2.66 1.15 2.96 2.00	.875 .845 .79 —	.4 .2 .413 .326
9	Foxhall, 116th St. & Amsterdam Ave.	March, 1902.	None.	74′–11″	150′	150′	150′	2000	300	2-phase motor, 200 volt, 60 cycles.	2 people up. 2 " down. 8 " up. 8 " down.	210	189 186 184 188	38 40 46 35	38 38 36 38	3.4 1.8 6.6 0.8	.95 .97 .93 .96	.43 .41 .68 .14
10	Elizabeth Apartment, 105th St. & Broadway.	1901.	Two-voltage control.	75′	200′	181′	185′	—	725	2-phase motor, 200 volt, 60 cycles.	2 people up. 2 " down. 3 " up. 3 " down.	6 173 60 175 60 175 60 175	122 146 104 132 113 152 104 144	4.4 11.2 2.0	8.5 14 6 8.6 6.4 14-4 2.0 36	1.6 1.0 2.0 0.4 4.8	Starting currents on points of control:	
11	Brambach Piano Co., 123d St.	June, 1901.	Rheostat control.	56′–6″	100′	18% variation with load.	18% variation with load.	2000 freight	500	15 type F. 2-phase motor, 200 volts, 60 cycles.	1 man and car up. 1 " " " down 12 0 pounds up. 12 0 " down 2 people in car up.	200			70 29 26	25.2 23.6 25.2	9.4 4.4 2.0 4.7	1 2 3 4 70 90 60 140 70 70 80 130 70 90 60 140

nating and the other direct current. In the hope of bringing forth further facts concerning this matter, investigations were undertaken to determine the power consumption in the two different lines. The work has been successfully conducted by Messrs. Rosenblatt, Daniels and Haviland, senior students in the Electrical Engineering Department of Columbia University, by making numerous tests on elevators of the different types providing similar service. Twenty such tests have been made and the results of the most characteristic installations are given in the appended table. The first five relate to direct current and the subsequent tests to alternating current motors.

It will be noticed that these investigations have been made in widely different sections of the city, with the alternating cur-

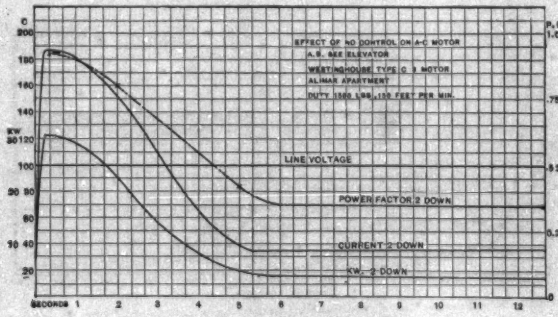

AREAS OF CURVES REPRESENT ENERGY IN K.W. SECONDS FOR 80 FEET RISE WITH 2 PASSENGERS
A
AVERAGE OF ALTERNATING CURRENT
B
AVERAGE OF DIRECT CURRENT
AREAS OF CURVES REPRESENT ENERGY IN K.W. SECONDS FOR 80 FEET DROP WITH 2 PASSENGERS
A
B
TIME IN SECONDS

Curve Sheet Nos. 1 and 2.

rent installations in that part where direct current is not available. The types of control for the direct current motors are known as magnet control, although No. 3 is regulated by hand. Four of the alternating current motors have no method of control, the current being thrown directly on to the motor by a switch. No. 10 has what is known as a two-voltage control, using two transformers, one giving 60 volts for starting and the other 175 volts for the running voltage. No. 11 has a rheostat control. This is arranged in such a way that resistances are altered in the rotor of the alternating current motor giving four steps from stand-still to full speed.

One very interesting point in connection with the alternating current motors is the power factor. It will be noticed that the starting power factor varies from .79 to .97, according to the load

upon the motor. In contrast to this, the power factor, while the elevator is running, varies from .14 to .68, the average being .36. This shows that the alternating current motor is much larger than the average conditions would call for, but it seems necessary to provide this capacity in order to accommodate any heavy loads that may have to be carried on a few occasions. The inrush of current for the alternating current motors is large as compared with that for the direct current machines, especially in those cases where there is no control. In test No. 11 with the controlling system using resistances in the motor, the inrush currents are maintained at a value comparable with those used in the direct current motors.



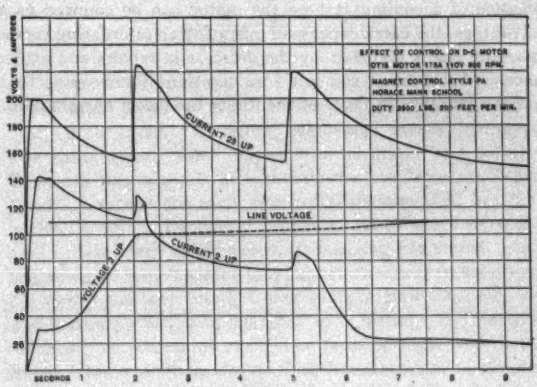
Curve Sheet No. 8.

In test No. 1 of a direct current elevator with 23 people carried up, the current at starting, is 199 amperes with running current of 150. In tests Nos. 6 and 8 with only two or three people carried up and down, the current varies from 170 to 193. In comparing the kilowatts for starting in these two cases, we find 19.8 for the direct current elevator and from 29.6 to 34.7 for the alternating current machines. Test No. 11 would seem to indicate the method by means of which the power consumption for alternating current motors may be decreased and thereby make the cost of operation less than it is at present for similar types of machines.

The above tables simply indicate the actions of the various types of elevators, and it is not advisable to compare the two classes of elevators as to economy from the results shown. In

order that a comparison might be made between all the tests which were conducted, curve sheets Nos. 1 and 2 were prepared.

Curve sheet No. 1 shows the average energy for all elevators through a rise of 50 feet carrying two passengers, the energy being expressed in kilowatt-seconds. Curve sheet No 2 shows similar values for the descent of the elevator. Curve A on curve sheet No. 1 shows the average of the alternating current and curve B that for the direct current tests. The areas of these two curves are to each other as 1.509 is to 1. This shows a percentage against the alternating current elevators of 33 per cent. Referring to curve sheet No. 2, and comparing the al-



Curve No. 4.

ternating current curve A1 with the direct current curve B1, we find a relation of 1.079 to 1, showing a power consumption for the alternating current machines greater by about 8 per cent. The curves for the direct current tests are made from the results of five motors with automatic control, while the results for the alternating current machines are made from six uncontrolled motors.

Curve No. 3 shows a typical alternating current motor with no control. The starting current with elevator going down is 186 amperes, while the kilowatts at this point are 30-5. The course of the power factor is interesting, it being. 92 on starting,

rapidly falling to .35 when the elevator is running at a uniform speed. Curve No. 4 shows the effect of control on direct current motors with a considerable overload. The current with 23 people in the car rose to 200 amperes and made an upward jump, reaching 225 amperes at the next point in the control. The variation in the voltage across the motor is shown by the voltage curve and this record would seem to indicate that the resistances of the circuit could be increased to advantage.

With the cost of power at ten cents per horse-power hour for both types of elevator, it would appear more economical to use direct current elevators in those places where both direct and alternating current are available. If the controlling apparatus is more simple with the alternating current system and the absence of a commutator on the motor can be counted as an advantage, the extra expense of operating an alternating current machine might be offset by the decrease in repairs and attendance. Apart from the last considerations there seems to be every advantage in favor of the use of the direct current motor.

A paper read at the 169th Meeting of the American Institute of Electrical Engineers, New York and Chicago, April 25, 1902.

TELPHERAGE.

BY CHARLES M. CLARK.

Definition. Telpherage is derived from two Greek words "τελε" and "φερω." "Tele" means far, and "ferro" means to bear or to carry. Therefore, telpherage means far-carrying. The same word "tele" appears in telegraph and telephone. The word was originally invented by the late Professor Fleeming Jenkin, who was the early spirit of telpherage, and but for his untimely death, telpherage would be even more extensively used. Like many other words, its meaning has varied. In the beginning it meant, practically, aerial electrical transportation, but now it has been brought back to its original meaning, which is the transportation of material to a distance by electricity, overhead, or sometimes on the surface, or even underground. In the latter case, it is termed "tubular despatch." Therefore, telpherage may be concisely defined as the electrical transportation of material. The method of applying it is an engineering problem and must depend upon local conditions, and even to-day the term "telpherage engineering" is becoming a common expression. It will be noticed that the word "automatic" is left out in these definitions. The reason for this is that it is a commercial question, and in cases where a man is required to attend to certain portions of the work, it is often cheaper for the man to go with the load than to use automatic devices. As to whether it is better to make an installation automatic or otherwise, depends entirely upon the comparative cost of the two methods of operation. In this connection it may be said that with telpherage plants the word "telpherman" is now often used.

FIG. 1. Side bearing telphers with permanently attached trailer. Track solid rail. Telpher controlled from either end. Length 1,200 feet. Four curves one "S" curve. Grade 12 per cent. Maximum total 4,000 lbs. Speed on level 10 miles per hour. Speed on grade 5 miles per hour Horse power—5 horse power. Capacity, 100 tons per day per telpher.

History. The early history of telpherage closely resembles that of the electric railway. Before the successful pioneers in electric street railway traction had finally accomplished satisfactory results, many men had experimented, and it is well known that, some forty years ago, an electric railway was operated, having a speed of several miles per hour. It seems that it is necessary, with all successful applications of power to the transportation problem, that much preliminary work, seemingly unproductive, must be done. It often happens, as in the case of early telpherage, that the time was not ripe for its commercial adaptation. In the history of telpherage in England, a telpherage line was installed, using what was then called the series system, whereby it was necessary to use a telpher with a number of trailers. One section was positive and the next negative, the current passing from one section of the track to

FIG. 2. Track of above showing "S" curve.

the other through the motor, thereby completing the cricuit. In passing over the insulator between the positive and the negative sections, there necessarily occurred considerable sparking, which greatly increased the cost of maintenance. It was also necessary always to have trains of certain lengths. There were many other disadvantages, such as having to use a track made of round bar rail and the difficulty of manufacturing reliable electric motors. If it was desired to install a telpherage plant, it was always necessary to put in an engine, boiler and dynamo. In comparison with its early history, telpherage to-day possesses the advantage that every factory, where there is need for tel-

pherage, either has its own electrical plant, or the power may be rented from existing central stations or even street railway stations. There are also to-day for aerial transportation most excellent cables made especially for telpherage work, and likewise, where it is more desirable to use than solid rail cable, special shapes have been devised which give most excellent results. Motors, controllers and carriers of great reliability are now manufactured following the methods developed by the best railroad practice.

Before it was decided to enter into the present commercial adaptation of telpherage, an engineer visited all the electrical manufacturing plants and electrical installations in Europe, and found that nothing was being done in the transportation of material electrically. In the United States many experiments had been made, but the inventors were always seeking the unobtainable. Upon careful research, it was found that there were 450 patents directly applying to telpherage and several hundred more which pertained indirectly to this subject. Most of these original inventors, were, however, too ambitious, and there was hardly any limit to the number of miles per minute which was to be achieved by the new and wonderful agent, electricity. Not only material was to be transported, but also passengers, and beautiful cars of mahogany were built and put in experimental operation. Cigar-shaped carriers were devised, some of which made a speed of two miles per minute or more, and when it was impossible to attain a greater speed there was great discouragement. There are no authentic examples of much more than experimental work, namely, merely conveying material between two points, generally in a straight line, placed in some vacant lot or loft, and there seemed to be a desire to force the method of transportation according to certain preconceived ideas, rather than to pay the necessary attention to its commercial adaptation.

Construction. On account of various advantages in regard to the distribution of material—such as depositing at an elevation—most of the telpherage plants thus far installed, have been overhead. As engineers, you will be most interested in hearing what has been accomplished; the descriptions are, therefore, confined to overhead work. Under the head of construction, it may be stated that the track is made of cable, especially drawn, either of standard wire or lock coil type, which latter has a strength approximating 95 per cent. that of the solid bar, or else solid rail, either of flat, girder or bulb type.

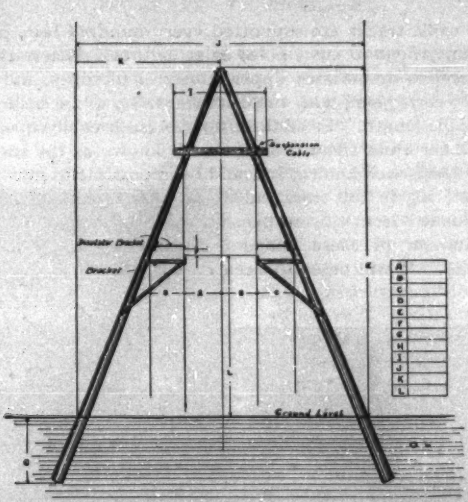


FIG. 3. SUPPORTING POLE, DOUBLE LINE. One of the simplest methods of pole construction for double lines. Especially recommended for long lines and where trees are available.

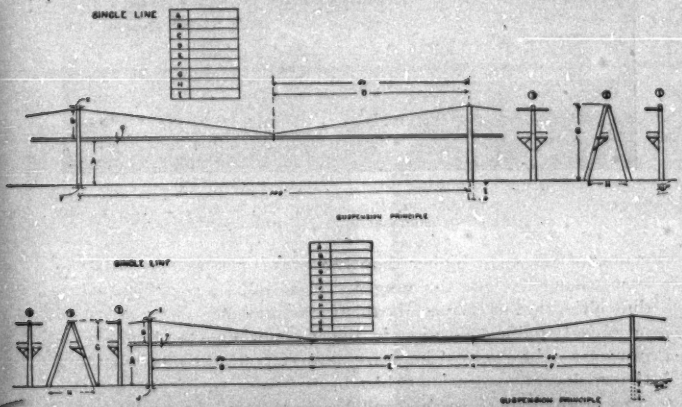


FIG. 4. OTHER FORMS OF POLE CONSTRUCTION, SHOWING SINGLE AND DOUBLE LINES. The track cables are supported by another cable, which is called the suspension cable. It would be impossible with long spans to stretch a cable so that under load there would not be considerable deflection. This deflection or sag is taken up by the suspension cable. Not only can we make the track cable horizontal, but even higher in the center than at the terminals.

The cable tracks are supported every hundred feet, provided it is convenient to erect poles or structures. Where there are deep ravines or between upper stories of factories, the span is made to correspond with the distance, and may be made of any reasonable length. In addition to the track cable, upon which the telpher runs, there is also what is known as the suspension cable. As is well known, it would be impossible to prevent considerable sag in the track cable and therefore the track cable is suspended from this suspension cable by means of hangers. The number of these hangers depends upon the length of the span. It will be easily seen that it is possible to have the

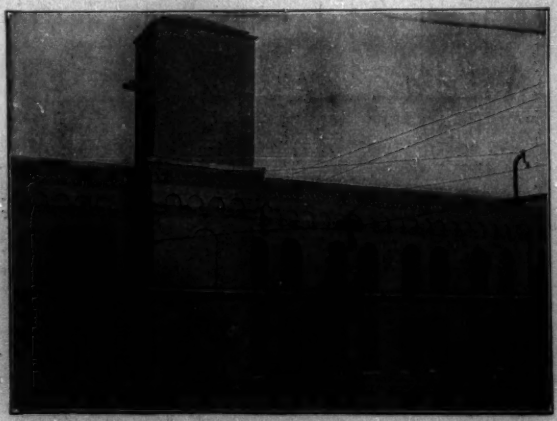


FIG. 5. Cable construction, Pittsburgh, Pa., line 97 feet from the ground, illustrating suspension cable, track cable and hangers.

center of the span higher than the ends, by merely raising the suspension cable and the hanger. This obviates one of the early difficulties met in the use of cable for telpherage, as there is now no objectionable deflection in the cable when the telpher approaches a bracket. There are several methods of connecting the track and suspension cables by means of the hangers. The sizes of the cable, hangers and brackets vary, depending upon the weight which comes upon each individual span. The support is either simple poles with a bracket, or what is known as the "A" construction or ordinary cross bents. Cable con-

struction costs less than solid rail, except where there are many switches, in which cases the prices of solid rail and cable approach each other. In general, cable lines is recommended for straight lines, except where the weight is excessive.

In solid rail construction, the supports are ordinarily placed sixteen to twenty feet apart; longer spans are used if it is not convenient to erect supports. On long spans, the track consists of a girder rail with the track rail above it. It is not possible to give any general rule, as to what kind of track it is advisable to use, as this is a factor of the length of the spans and the

FIG. 6. Examples of cable construction with telpher, electric hoist and bucket, Elizabethport, N. J.

weight. The weights conveyed thus far by telpherage vary from 125 to 10,000 lbs. and the cost varies accordingly. It will be readily understood that when the weights are greater, the supports must be nearer together, and the cables or girders heavier. Running parallel to the track rail, either above or at the side, depending upon the amount of head room, are stretched one or more trolley wires; one wire, if the track is used as a return. If, however, it is desired not to use the track as a return, or to use alternating current, two trolley wires are employed. There are many other details of construction, but the photographs and outline drawings will serve to illustrate better than any description.

FIG. 7. Solid rail combined with cable construction. Capacity, 150,000 lbs. of ashes in ten hours. At present, handling the ash output of 23 boilers with other refuse. Average power consumed about one horse power. Located in New York City.

Telphers. According to the construction, telphers are divided into three distinct classes, center bearing, side bearing and alternate bearing. The center bearing has two motors, one on each side of the track; the side bearing has both motors on the same side, and the alternate has one motor upon one side of the track and the other motor upon the other side, but not upon the same shaft. Illustrations of each kind (Figs. 8, 9, 10, 11 and 12) are shown, also the same in operation. All the weight, in the side-bearing telpher, is utilized for traction, and the load is suspended

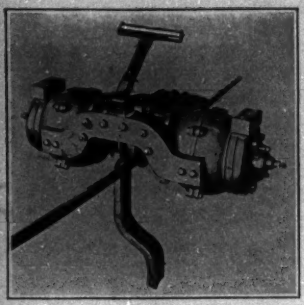


FIG. 8. CENTER-BEARING TELPHER.

FIG. 9. TELPHER WITH SOLENOID SPEED REGULATOR FOR GRADES AND REVERSING SWITCH.

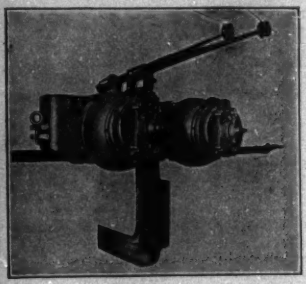


FIG. 10. FRONT VIEW. SIDE BEARING. DOUBLE TROLLEY.

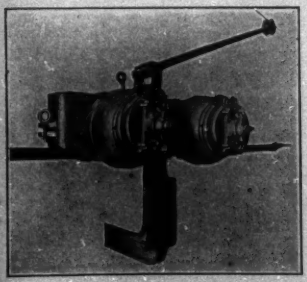


FIG. 11. SINGLE TROLLEY. SIDE BEARING.

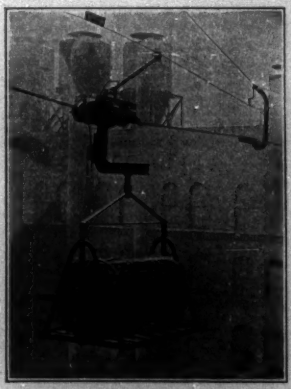


FIG. 12. Side bearing telpher in operation. Illustrating method of suspension, also the carrier, section insulator, hanger, suspension and track cables with trolley wire.

beneath the driving wheels. Sometimes two telphers are connected up together in a single truck, this giving what is called a double telpher; or a trailing wheel is used after a double telpher, in order to distribute the weight over a greater portion of the track. This is necessary when the weight of the load to be carried is great. Fig. 13 shows quite fully this weight distribution. In all telpherage work, gears are rarely used except for very heavy work or on steep grades. The frames of the later telphers are made in one casting, and the driving wheels are of steel, this having been determined to be the best material.

Motors. The motors are waterproof and dustproof and are compound wound for automatic work. When a telpherman goes with the telpher, the series winding is employed. There is also used a special series coil to give greater torque when starting. The telpher is placed above the track, thereby keep-

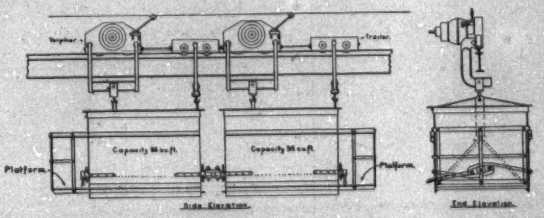


FIG. 13. The double telpher; maximum traction; capacity, four tons of coal, or 95 cubic feet; speed, 800 to 1,200 feet per minute. Side-dumping bucket operated by telpherman; controlled from either end. Telphers can be operated separately.

Three of these double telphers have a capacity of 250 tons of coal per hour over 2,000 feet of track. Labor, power and maintenance less than one cent per ton.

ing the motors from injury, while there is also no danger of their coming in contact with the carriers or being otherwise injured.

Hoists. The hoist is suspended below the telpher, or sometimes from a trailer drawn by the telpher. Special attention has been paid in the later designs of hoists to use as little head room as possible. It was deemed best at first to combine the telpher and hoist, but there were so many cases where it was necessary to use the telpher alone without the hoist, and also where it was advisable to put the hoist on the trailer instead of on the telpher, that experience has shown that it is better to make the telpher and hoist two separate pieces

of apparatus. Greater simplicity has also been obtained, and a correspondingly lower maintenance reached. There are many other interesting details concerning hoists, as to the speed, lift and construction, which it is necessary to omit here.

Brakes. Two distinct types of brake are used on telphers, either hand brakes or solenoid brakes, both of which are arranged to apply pressure to the wheels or to grip the track. In regard to the solenoid brake, it is only necessary to explain that it works automatically, the solenoid being placed in series with the armature. A spring normally holds the brake on the

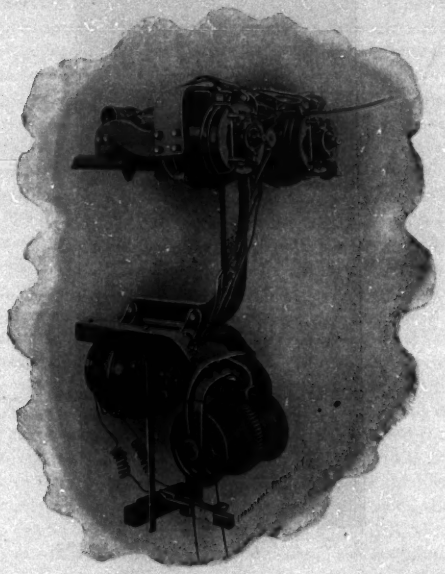


FIG. 14. ELECTRIC HOIST SUSPENDED FROM TELPHER.

wheel or the track. If, however, from any cause, the amount of current passing through the solenoid is reduced, whether by means of external resistance or by reason of the additional counter-electromotive force generated by the armature, due to running at a high speed, the solenoid becomes weakened and the brake is applied. An air cushion is arranged so that the brakes will be applied gradually.

Trailers. It is often advisable, where a large amount of material is to be carried, especially over one track, to use trailers. These consist generally of a two-wheeled truck, below which is suspended a bucket or other suitable form of carrier, or even the hoist, as the case may require. It is customary where a large amount of material is to be carried, to arrange a long train carrying as much as ten tons. The order of procession is, first, a telpher with four or five trailers, then another telpher and four or five trailers, and a telpher at each

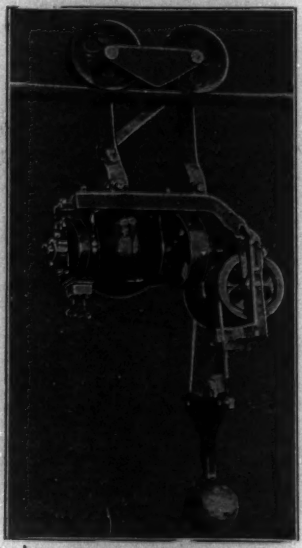


FIG. 15. ELECTRIC HOIST AND TRAILER.

end. The placing of these telphers at intervals greatly adds to the traction, while the distribution of weight over the whole span, or over two or three spans, enables much lighter construction to be used for greater capacity.

Layouts. Much engineering skill is required to lay out or plan the telpher lines for any proposed work in order to decide whether the line should be single or double, and the weight to be carried by each unit. The installations should be so

planned that the expense will be reduced to a minimum, and further, that the track will not interfere with existing machinery or buildings, taking care to avoid an excessive number of curves and switches, as these add more or less to the expense, particularly to the cost of erection. It is necessary therefore, for the selling engineer to be thoroughly trained in this part of the work, or else have the necessary engineering knowledge derived from some other similar business. It may readily be understood that it is impossible to give general prices for telpherage work. Complete specification blanks, with many necessary questions, are, therefore, provided, and the replies to these questions, together with a blue print showing a plan and elevation, are generally sufficient for the company to give a complete estimate for any proposed installation.

Method of Operation. It is difficult to treat in a general way of the method of operation. In automatic lines it is necessary to provide appliances whereby it is impossible for an unskilled operator to injure the telpher. In order, therefore, to provide for contingencies, a "dead section" is placed at each end of the line, the middle of the line being generally left alive. Upon closing a spring switch, the dead section is energized so long as the operator keeps his hand on the switch, which is usually only a few seconds, during which time the telpher passes to that portion of the line which is always alive. When it reaches the other end, it comes upon the dead section and then either slows down of its own accord, or else a mechanical or solenoid brake is applied. The telpher then passes under the reversing arrangement and it is therefore reversed, either with no current in the line or else with a high resistance. If the telpher is at the further end of the line, the operator at the near end, by closing a switch, can bring it back to him. The dead sections at the end of the line, which have current only so long as the hand is held upon the spring switch, render the line as safe as possible against the telpher coming in contact with the terminal posts. An automatic block system prevents collision of telphers.

Curves. The curves are solid rail and likewise the trolley track, where there is a curve, especially when it has a short radius. Wherever it is necessary to pass around a curve, to take turnouts or crossovers, a resistance is inserted in the trolley circuit, whereby the telpher automatically reduces its speed while it is traversing the curve or turnout or approaching a crossover switch. As soon as it reaches the other side of the

curve it receives full voltage and continues at its normal speed. In regular service the speed varies from 300 or 800 feet per minute, up to 20 miles per hour, or even more, when required. The slower speeds are used when the lines are short and where there are many curves, particularly for factory and foundry

FIG. 16. TELPHER WITH AUTOMATIC DUMPING BUCKET TRAVERSING A CURVE. This shows a telpherage plant located at Buffalo, N. Y. This installation is interesting on account of its automatic features. The bucket is loaded at the cars and the load is transported by electricity to the end of the line, where the bucket automatically dumps its load. The telpher reverses itself and returns with the empty bucket to the cars for another load. The telpher may be operated by unskilled labor with the minimum of expense for power, maintenance and first cost. Power is less than one horse. The material which is dumped into a hopper is then elevated to the upper story. This line consists of a straight section and a right angle curve. A portion is cable, and the curve and the track in the building are solid rail. The line is supported, as will be observed from the photograph, from ordinary telegraph poles, and is an excellent example of simple construction.

work. For lines running across the country a speed in excess of 20 miles per hour can be obtained, but with the higher speeds the cost of the construction increases, certain special devices being necessary. Even for installations which are termed "cross country work," 15 to 20 miles per hour has been found amply sufficient.

As to what the ultimate capacity on grades may be, this has not been fully determined. Experimentally more than 20 per cent has been reached. In actual practice the greatest grade equipped has been 12 per cent., and thus far there seems to be ample traction.

THEORETICAL HORSE POWER NECESSARY TO PROPEL 1,000 POUNDS AT VARIOUS SPEEDS AND UP VARIOUS GRADES AT SAME SPEEDS.

Grades in per cent.	SPEED IN MILES PER HOUR.													
	1	2	3	4	5	6	7	8	9	10	12	15	20	25
0	.027	.053	.080	.107	.133	.160	.187	.213	.240	.267	.320	.400	.533	.667
1	.053	.107	.160	.213	.267	.320	.373	.427	.480	.533	.640	.800	1.07	1.33
2	.080	.160	.240	.320	.400	.480	.560	.640	.720	.800	.960	1.20	1.60	2.00
3	.106	.213	.320	.427	.533	.640	.747	.853	.960	1.07	1.28	1.60	2.13	2.67
4	.133	.267	.400	.533	.667	.800	.933	1.07	1.20	1.33	1.60	2.00	2.67	3.33
5	.160	.320	.480	.640	.800	.960	1.12	1.28	1.44	1.60	1.92	2.40	3.20	4.00
6	.186	.373	.560	.747	.933	1.12	1.30	1.49	1.68	1.87	2.24	2.80	3.73	4.67
7	.215	.427	.640	.853	1.07	1.28	1.49	1.71	1.92	2.14	2.56	3.20	4.27	5.33
8	.241	.480	.720	.960	1.20	1.44	2.68	1.92	2.16	2.40	2.88	3.60	4.80	6.00
9	.267	.533	.800	1.07	1.33	1.60	1.87	2.13	2.40	2.67	3.20	4.00	5.33	6.67
10	.293	.586	.880	1.17	1.47	1.76	2.05	2.34	2.64	3.03	3.52	4.40	5.36	7.33
11	.320	.640	.960	1.28	1.60	1.92	2.24	2.55	2.88	3.20	3.84	4.80	6.40	8.00
12	.346	.693	1.040	1.38	1.73	2.08	2.43	2.77	3.12	3.46	4.16	5.20	6.93	8.67

Although the amount of power may be easily figured out, it is somewhat in the nature of a surprise when we consider that to carry half a ton on a level track at a speed of six miles per hour, much less than a horse power is required, including all losses. This is a revelation to most manufacturers. The absence of gearing, the motors being attached directly to the driving wheels, gives the highest efficiency possible, as well as freedom from noise.

The actual power consumed, according to the table given above, at six miles per hour for 1,000 pounds on a level is only .16 h. p. It is, therefore, seen that ample allowance is made for losses and extra weights not provided for in the load, such as down-comes, buckets or carriers. The power required increases greatly with the grades and when this reaches certain limits it is deemed advisable to use gears in order to reduce weight of motors.

Maintenance. Although telpherage has not as yet been in operation for a sufficient number of years to determine exactly what the maintenance will be, yet, at the same time, in lines that have been operated for a year and a half, the maintenance has been exceedingly small. As stated above, the driving wheels being of steel, none of them has thus far shown any signs of wear, and trailer wheels are of the same material and type

as those which have been used on mechanical cable lines for ten years and are still in good serviceable condition. The motors, on account of their elevated position, have shown a better maintenance than stationary motors of the same type. This may possibly result from the extra care taken in their construction. In regard to the track, this has also shown most excellent results, also due to the fact that it is above grit and dirt and crossing teams and, when well painted, has shown little signs of wear or depreciation. Wherever a change is made from cable to solid rail, or where cable passes over hangers or brackets, it is pro-

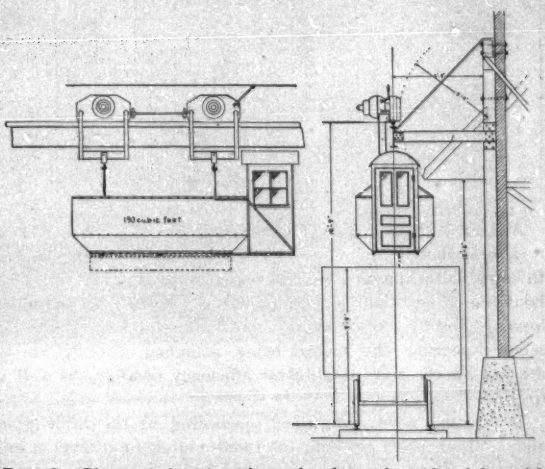


FIG. 17. Plan and elevation of another form of double telpher with four-ton coal bucket, bottom dumping, cab for telpherman. The side elevation shows method of attachment to side of building and loading chute.

tected by what are called "shields," these being arranged so that they may be readily replaced. The cable is also protected at the hanger and brackets by steel shields.

Capacity. An important feature in telpherage is the capacity of the line. In general, I can say that there is no other form of conveyor known which shows such flexibility. This is due to the use of electricity, and the features which apply to the street railway, apply also to telpherage. There are two factors of special importance in relation to the capacity of the line:

first, the speed, and second, the number of telphers and trailers. The line may be laid out with one telpher and a few trailers. More telphers or trailers may be added, and, if upon a single line, coupled in long trains. If it is desired still further to increase the capacity, the line may be made double, while if de-

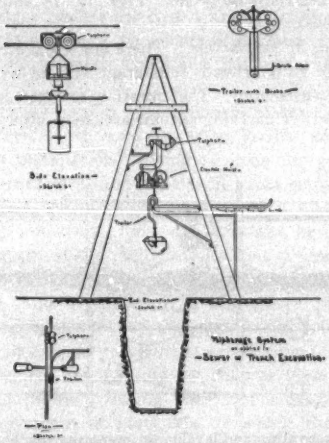


FIG. 18. In sewer or trench excavation the method of operation it as follows: The bucket has attached to it a trailer wheel. The buckets and wheel are lowered into the excavation, and the bucket, when filled, is raised by the electric hoist so that the wheel of the trailer engages the gravity rail. The load then passes by gravity to the place desired and is automatically dumped. This may be along the line of excavation, for refilling the trench, or to the right or left, for unloading into carts, or in connection with the telpher to any desired distance. The telpher has the flexibility of a trolley car. This method is a combination of telpher and gravity lines, and the amount of work that can be accomplished by it with the minimum of labor is remarkable.

sired, the carriers may also be made continuous so as to take boxes and barrels or other freight as fast as they can be delivered to the carriers of the telphers and trailers.

The flexibility of telpherage in regard to capacity is wonderful, and is a most important feature. In fact, it may be said that there is practically no limit to flexibility. In one plant, about to be installed, the proposed capacity is 250 tons per

hour, over a distance of one-half a mile, the material to be distributed over an area of about an acre. Any one who is familiar with conveying will note that there is no other system that can do this so economically, and in a way so thoroughly satisfactory as telpherage.

The nature of installation varies with the amount of material to be carried, so that if the amount to be carried is small, the expenditure need not be great. Figs. 17, 18 and 19 show various applications.

Applications of Telpherage. There are few factories where the installation of an overhead telpherage system would not prove a valuable investment. The question is often asked: Is telpherage suited for carrying specific articles? And the reply may

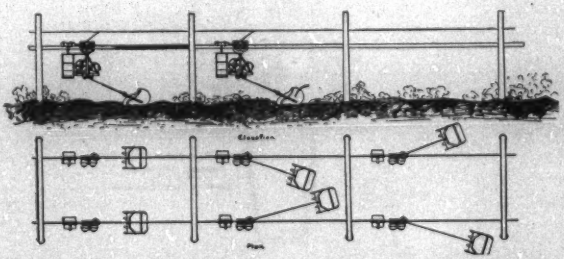


FIG. 19. Excavating and leveling in preparing roadbeds for railroads. The function of the telpher is to transport the hoist, bucket and load. The hoist does the excavating and elevating. The hoist automatically brakes itself either upon the girder rail or grips the cable as soon as there is any longitudinal strain. Used also for scooping and transporting earth, sand, ashes or coal.

be made that it is adapted to the conveying of the products of almost every kind of manufacturing.

In these days of consolidation of companies, factories cover immense areas. The individual buildings are frequently large enough in themselves to utilize a telpher line. In many cases, on account of fire risks or of convenience in manufacturing, the buildings are widely separated from each other, and yet constant communication is necessary. Overhead telpherage, therefore, in manufacturing establishments is used for carrying the raw material, implements and finished products from one part of the grounds to another, from one building to another, or, even from one part of a building to another part, moving raw material from

cars or vessels to the works and then taking the finished products to the railway station, or the wharf, for shipment; and for conveying refuse away from the factory. In this connection we might mention the conveying of ashes or slag to the dump heap.

Telpherage may also be extensively used for handling coal. It serves to reduce greatly the cost of transportation on plantations and farms and may be economicallyused for handling coffee, sugar cane, tobacco, fruits and hay and other like products.

In general, it may be said, that wherever material is to be carried to a distance, there is no power so flexible, so economical in first cost of installation, costing so little for power or the expense of maintenance, and with such great capacity as telpherage. It may, therefore, be designated a material transportation by an immaterial fluid, and may well be called one of the most important of the many adaptations of electricity.

If time, floor space, or labor is being consumed in the conveying of any kind of material in any plant, plantation or mine, each can be saved by the installation of telpherage. Any condition at any manufacturing establishment which presents a requirement for hauling by man or team, whether in transmission of product during the various stages of manufacture, the movement of materials by which the product is to be treated or the handling of fuel, and ashes or other waste, is a logical opening for the installation of telpherage.

When you install telpherage you employ a machine to do the work of men. Machinery is the most powerful factor for economy in production. Telpherage is almost human in its operation, works any number of hours per day and never tires. In many cases you start the telpher, it conveys, automatically leaves its load at the destination and returns for another load. Telpherage conveys 50 lbs. or 50,000 lbs. solids or liquids.

Much more can be said about telpherage, but the above will give a general idea of its work. Many plants have been installed and many more are being installed daily, and in many instances duplicate orders are being received from former customers.

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SOME NOTES ON EUROPEAN PRACTICE IN ELECTRIC TRACTION WITH THREE-PHASE ALTERNATING CURRENTS.

BY CARL L. DE MURALT.

There have recently been some pretty lively discussions between the advocates of continuous current and those of alternating current systems for electric traction purposes.

Now I wish to state right at the beginning that in the opinion of the author there are certain cases where continuous current is preferable and where alternating currents could not do the work as well, on the other hand there certainly are cases where alternating currents are particularly well adapted to solve the problems in question and where continuous current could not be used advantageously. Each special case should therefore be studied by itself, and the decision as to what system should be adopted ought to be dependent on all the different conditions which might apply to the particular case, viz., profile of the road, speed required, number of stops, traffic conditions, etc., etc. Probably most of us will agree for instance that, taking everything into consideration, the recent decision in the London Underground Railway case was really the best solution of this rather complicated problem.

In America continuous current practice has so far almost absolute sway, and it may therefore be interesting to learn something of what has been done in Europe, and more particularly in Switzerland, in the way of using alternating currents for traction purposes and to hear at the same time something about the practical results obtained on some alternating current roads that have been in operation several years.

Brief descriptions follow in chronological order of some of the most typical roads of this kind including as many details as possible, especially in regard to the Burgdorf-Thun Railway, probably the best example of an alternating current railway installation. The results of some tests made on this latter railway are also given with a few general conclusions as to the applicability of polyphase alternating currents for traction purposes.

First Tests by Siemens & Halske.—The first tests with alternating current traction were made by Siemens and Halske of Berlin, in 1892, in Charlottenburg on a specially constructed track of about 360 m. length with one curve of 40 m. radius. There were two overhead trolleys, the rails forming the third conductor. The voltage was between 500 and 600, the periodicity 50 cycles per second. An open car was used on an ordinary street railway truck, equipped with a three-phase induction motor driving one of the axles by means of a single reduction gear of 1 : 11. The speed of the motor being 1400 revolutions per minute; the maximum speed attained was about 25 km. (15 miles) an hour.

The primary winding of the motor was arranged to allow being connected in delta for starting purposes, while it was changed to star connection for full speed. The starting torque of the motor was therefore made about six times the full load running torque. The motor was also provided with slip rings on the rotor which allowed for inserting resistance into the secondary winding.

These tests showed clearly that an alternating current railway was absolutely feasible, and proved that no serious difficulties would be encountered in regard to the trolley line construction. However, the street railway problems then under consideration did not absolutely require the use of anything else but the well known continuous current system and this is probably the reason why these tests were not carried any further and put into actual practice.

The installation as just described was sent to the Chicago Exhibition in 1893, where it attracted considerable attention, but nothing has been heard of it since.

Lugano Tramways.—Brown, Boveri & Co. of Baden, Switzerland, may claim the honor of first putting alternating current into actual use for traction on a commercial scale. The tram-

ways of Lugano, the first three-phase railway, were opened for traffic in 1895. The power station for these tramways is 12 km. outside of town, therefore transmission with 500-600 volts continuous current was impossible. Rotary converters seemed too expensive and thus it happened that all conditions were favorable for an experiment with three-phase alternating currents. The total length of the line is 4900 m. (about 3 miles) with maximum grades on long stretches of 3% and on short stretches of 6%. The transmission voltage is 5000 volts at 40 cycles. Transformers reduce this to 400 volts. Two trolley

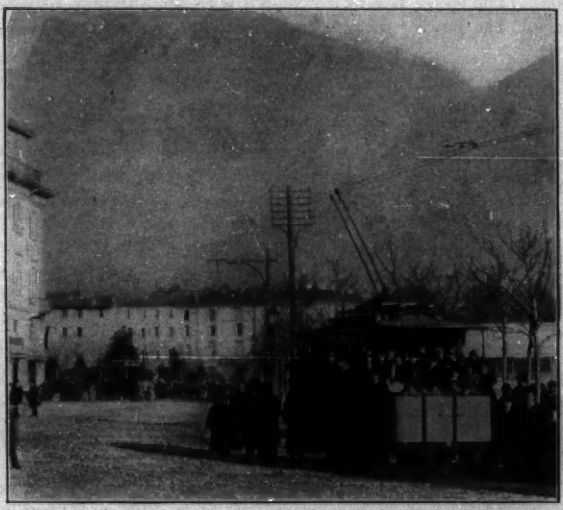


FIG. 1.

wires of 6 mm. diameter 25 cm. apart are used and the rails serve as third conductor. Cars hold 20 persons each. There is one 20 h.p. motor per car, completely enclosed, with single reduction gear 1 : 4. Speed of car 15 km. (9.3 miles) an hour. Two trolleys, one 1 yard behind the other, make contact with the two lines. Motors are started by means of a reversing switch and their speed is controlled by means of a resistance in the rotor circuit. Cars may be handled from both platforms.

Fig. 1 gives a good idea of one of these cars, and shows part of the line. Tests have demonstrated that it is possible to start with ease even on 6% grades and under more than full load.

Gornergrat Railway.—After the Lugano plant had thus proved that alternating currents could be applied to ordinary tramway purposes, the Gornergrat road was destined to show that they could also be used to advantage on a much larger scale and under the most severe conditions met on a Swiss mountain road. The total length of this line is 9 km. (5.6 miles). The difference in altitude of the two terminals is 1412 m. (4660 ft.) The maximum grade is 20%, the minimum radius in curves 80m. The gauge is 1 m. (3′ 3 3-8″) with an Abt rack between rails. The power station generates 5400 volts at 40 cycles.

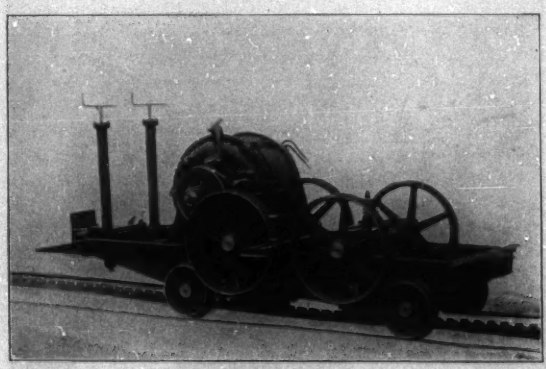


FIG. 2.

Three transformer stations of 180 k.w. each 2, 5 and 8 km. respectively from the beginning reduce from 5400 to 540 volts. The high-tension line follows a separate route. The trolley line consists of two wires of 8 mm. diameter suspended by means of cross-wires from wooden poles every 25 m. the rails forming the third conductor. The speed is 7 km. (4.35 miles) an hour and there are 5 stations, 2.5 to 3 km. (1.5 to 1.8 miles) apart. The normal train consists of one locomotive, one main passenger car, (60 persons) and one second car (50 persons) added when needed. As a maximum there are two trains up and one down on the road at the same time. The locomotive weighs

10.5 tons, two cars 9.2 tons and 110 passengers 8.3 tons, total for one train 28 tons. The motor capacity is therefore 160 h.p. or about 180 h.p. on axles, and the locomotive is equipped with two motors of 90 h.p. each, running at 800 revolutions per minute. Each motor drives by means of a double gear one of the two cog wheels. The total reduction of gear is 1 : 12. The motors are controlled by a reversing switch through which the stator is connected to the line and by the usual starting rheostat in the rotor circuit. The rheostat is placed on the top of the motors to save space, and the switch, fuses and instruments for the same reason on the side and against the roof of the car. Two trolleys are employed on each line wire on account of the large current and in order to pass switches without making a break. The motors start on any grade under full load without using more current than when running at full speed and full load. They can start under more than full load but with proportionately more current. Fig. 2 shows the truck of the Gornergrat locomotive with one of the motors in its place. This line was completed in 1897 and opened to traffic in 1898.

Jungfrau Railway.—Before it was finished, work was already begun on a very similar line, the Jungfrau Railway. The total length of this road is 13 km. (8 miles) with a difference in altitude between the two terminals of 2100 m. (6900 ft.) The grade, almost immediately after leaving the Kleine Scheidegg station, is 10% and this is increased to 20% at about half way to the Eiger Glacier Station. From there on, the grade increases to the maximum of 25% when the line enters the tunnel. The permanent way is of metre gauge with a rack of the Strub system half way between the rails. The sharpest curve on the open section has a radius of 100 m., in the tunnel this is increased to 200 m. Water power is made use of in the valley of the White Lutschine to generate three-phase currents at 7000 volts and 38 cycles, which is transmitted by overhead wires to transformer stations along the line, where it is transformed down to 500 volts. The sub-stations are stone buildings, designed to withstand the action of the most inclement weather. They are fitted each with two 200 k.w. transformers. When the whole line is completed, transformers will be placed about every 1000 yards. There is a double trolley line as on the Gornergrat. The locomotives are very similar to those on the Gornergrat line. They weigh 13 tons complete, and contain each two 125 to 150 h.p. induction motors, driven at 760

revolutions per minute. The motor controlling devices and the contact arrangements are exactly the same as on the Gornergrat road. The cars hold 40 persons each and a normal train consists of one locomotive pushing two cars, the total weight of such a train when filled, being 28 tons as on the Gornergrat road. The speed, however, is 8 km. (5 miles) per hour.

The first section of the Jungfrau Railway to Eigergletscher was opened in September, 1898, the second to Rothstock in April, 1899, since then each year has seen further progress toward the summit, which will probably be reached in five or six years.

Stansstad-Engelberg Railway.—The next alternating current

FIG. 3.

railway to be built was the one from Stansstad to Engelberg. This road, although of metre gauge only, approaches in the shape of its cars normal gauge railway conditions. The total length of the line is 22.5 km. (14 miles) The first 15 km. have small grades up to 2%, the next three km. have grades of 2.5 to 5%, then follows a section 1.5 km. long with a grade of 25% and a so-called ladder rack, finally about 3 km. more with grades of 2.5% and less. The minimum radius in curves is 50m. The power station is situated at the beginning of the rack section,

about 18 km. from Stansstad, therefore it is near the point where the maximum energy is used. The voltage generated is 750 volts at 32.5 cycles, and this is fed direct into the trolley line. A 90 k.w. step-up transformer produces 5,300 volts which is transmitted to two sub-stations situated at about 3 and 7 km. respectively from Stansstad and containing each a similar transformer, reducing the voltage again to 750 volts. The trolley line construction is similar to that found on the Gornergrat and Jungfrau Railways. There are nine passenger stations on this road. Three locomotives and seven motor passenger cars are used. The cars, as shown in Fig. 3, are of the double truck type, and their total length is 14 m. Each car weighs 14 tons and

FIG. 4.

has room for 46 passengers besides being provided with a baggage compartment. The front truck carries two motors of 35 h.p. each, running at 400 revolutions per minute, with single reduction for a car speed of 20 km. (12.5 miles) per hour. The contact with the trolley line is made by means of two double contact bars attached to the roof near each end of the car. The cars may be controlled from either end-platform and the control is similar to that already described for the other roads. One automobile car is able to propel itself and to haul a trailer of about

10 tons on grades up to 2.3%. The first 15 km. section, which happens to have the heaviest traffic, is therefore worked with two cars at a speed of 20 km. per hour. The next section with heavier grades up to 5% is traversed by the motor car alone at the same speed, the motors furnishing about 80-90 h.p. for a 16-ton load on a 5% grade. At the beginning of the rack section a locomotive is added which pushes the car up the grade of 25% at a speed of 5 km. an hour. The last stretch with grades up to 2.5% is covered by the automobile alone. The locomotive not only serves for the above mentioned purpose but is destined also to haul freight trains of 20 tons total weight over the lower part of the road at a speed of about 11.5 km. an

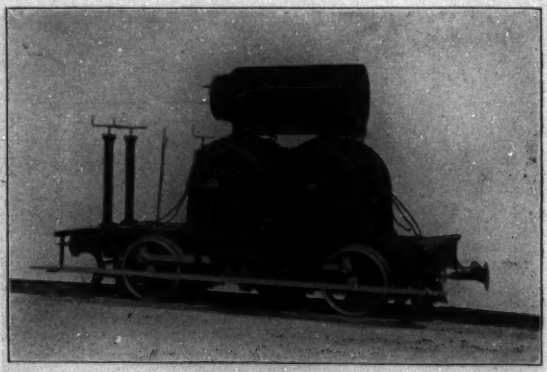


FIG. 5.

hour. Its design, therefore, varies greatly from the Gornergrat and Jungfrau locomotives. Two motors of 75 h.p. each and 650 revolutions per minute drive through a single reduction gear a counter shaft, which by means of two symmetrically placed gears drives the cog wheel placed in the center of the locomotive. This wheel is mounted on a hollow shaft fitted over the crank shaft which in its turn drives the four main carrying wheels of the locomotive On the rack section the cog wheel alone is driven. In the level country a friction coupling is set in such a manner that the two main axles are driven and the cog wheel is allowed to follow loose. The contact device is similar to the one on the passenger cars. Fig. 4 gives a good

idea of this locomotive and Fig. 5 shows an interior view of its mechanical arrangement, while Fig. 6 represents a locomotive pushing one of the passenger cars up the 25% grade. The Stansstad-Engelberg Railway was opened also during 1889.

Burgdorf-Thun Railway.—The Burgdorf-Thun Railway, which was opened in 1899 and which will be described more in detail is not exactly what you would call a trunk line, yet it is of normal gauge and forms a very important link between three of the main steam lines of Switzerland. The service conditions are the same as encountered on the other Swiss railways and it uses the same size and shape of rolling stock as the main

FIG. 6.

steam roads. The total length of the line is 40.3 km. (25 miles). The main reason for adopting electric traction was that the time-table could be arranged much more conveniently than for steam traction. With steam there would have been 5 trains per day in each direction, costing per year at the least 52,000 francs for coal alone and each additional train would have cost 10,000 francs more for coal alone. Now, 50,000 francs allows with electricity as motive power the running of 10 passenger and two freight trains per day in each direction over the whole length of the line, and besides three or four trains per day from Thun to

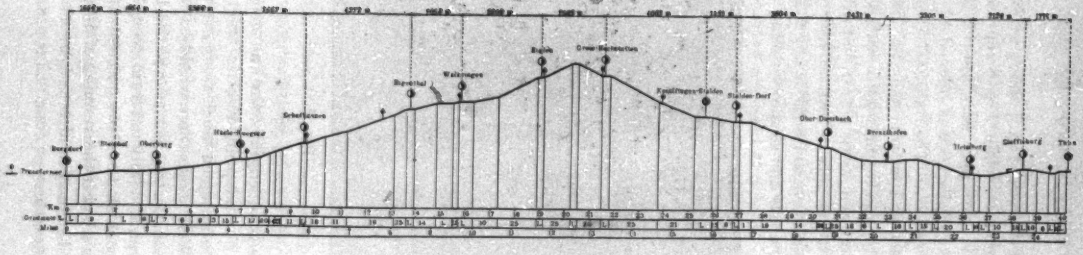

Burgdorf
Thunthal
Oberberg
Hasle-Rüegsau
Erlenbach
Signau
Walkringen
Eggiwil
Grosshöchstetten
Trachselwald
Sumiswald-Dorf
Ober-Denkbach
Bowil
Huttwil
Dietwil
Thun
Transformer
Km
Distanzen
Meter

FIG. 7.

Konolfingen and back. Each train consists normally of one motor car and one or two trailers with a total seating capacity of 130-140 passengers. This means that not only is the public benefited by a better service, but the number of passengers actually carried is larger and thus increases evidently the income of the railway by a handsome percentage. Fig. 7 shows a profile of this line. There are 16 stations, four of which have connection with existing steam lines. The gauge is normal = 1.435 m., the minimum radius in curves is 250 m

The road starts at Burgdorf (536 m. above sea) and ascends with an average grade of 1.144% to the highest point almost exactly half way between Burgdorf and Thun (770 m. above sea). Then it descends with an average grade of 1.051% to Thun (561.5 m. above sea). The maximum grade in any place is 2.5%. All stations have a level stretch at least 200 m. long: 64% of the total length is straight line; 36% curves; 24% level; 23.5% on grades up to 1%; 31.5% on grades between 1 and 2% and 21% on grades between 2 and 2.5%. Rails are 12 m. long and weigh 36 kg. per metre: 45% of the track is on iron sleepers weighing 137 kg. per metre track; 55% on wooden sleepers weighing 145 kg. per metre. The normal speed was fixed at 39 km. (24.2 miles) per hour.

The energy is furnished by the power station on the Kander about 10 km. (6 miles) beyond Thun. The primary line voltage is 16,000, the number of cycles 40 per second. Fourteen transformer stations reduce this voltage to the voltage in the trolley lines which was fixed at 750 volts, this being the limit set by the federal authorities at that time. This voltage, however, seems to be increased slightly in actual practice.

The number of transformers along the line was determined by the following considerations:

The distance between two transformers along the line had to be chosen so that the drop in the line voltage did not exceed a certain predetermined value. On the other hand it was desirable to keep the number of stations within a certain limit in order to make the proportion between installed and actually working transformers as favorable as possible. It will be noticed that at any time only those transformers between which trains are actually moving are under load, while the rest are not doing any work. Finally the transformers should be placed

as near the railway stations as is practicable so as to facilitate their inspection. These somewhat conflicting conditions led to the adoption of 14 transformer sub-stations with an average interval of 3 km. from one another, the maximum interval being 3.4 km., the minimum 2.4 km. The two end transformers are 500 m. from the terminals of the line.

The size of each transformer would really be dependent on the grades in its vicinity. As these grades are pretty nearly alike in this case, the capacities of the transformers worked out

FIG. 8.

to be very much the same also, and it was therefore decided to use only one size of transformer with a maximum output of 450 k.w. This is the power required to move two complete trains. Fig. 8 shows one of the transformer sub-stations.

The high tension line first passes an emergency switch which permits cutting off the whole station. The transformer is placed in a small iron house containing in its upper part primary and secondary fuses; there is also a lightning arrester on the top of each station. The transformers are of the oil cooled type and transform from 16000 volts down to 750 volts. On

the secondary side one pole is connected to earth, viz: to the rails, and the other two are carried over to the other side of the track, where they enter a special small switchboard placed in an iron box which allows cutting off the transformer from the line or else either of the two line sections meeting here from the transformer. The whole length of the line is thus effectively cut up into 15 sections. The secondary box also contains a secondary lightning arrester. Most of the sub-stations are also equipped

FIG. 9.

with a small 2 k.w. lighting transformer, furnishing the current for lighting the neighboring railway station.'

The trolley line consists of two copper wires of 8 mm. diameter suspended by means of steel cross wires from wooden poles placed on both sides of the track. These poles are normally about

35 m. apart somewhat less on curves and grade crossings. The height of the trolley wires above the rails is 5.2 m. (16 ft.) at the most, and at least 4.85 m. The rails form the third conductor and are bonded by means of a special metallic paste.

The contact devices of the cars consist of four steel frames per car as shown on Fig. 9, two on each end of the car roof at a distance of about 9.5 m. (31 ft.) from the other two, the contact bar being a brass roller of special shape. This double set was found to be necessary in order to facilitate the passing of switches without breaking the current. At the switches, the two outer trolley wires are carried right through, while the two inside ones terminate in insulated sections prolonged into a common meeting point and there anchored by insulated guy wires. The distance of 9.5 m. between the two sets of contact devices is just long enough to allow three of the four bars making contact under any condition. There is, therefore no sparking at switches, and it is possible to stop a car underneath a switch and to start it again in the same or the opposite direction.

There are two kinds of motor cars, the passenger automobile and the regular locomotive for freight trains. If this railway had been entirely independent the passenger trains would perhaps consist of one car alone. As it is, the traffic to be handled at the stations having connection with the steam roads necessitated larger carrying capacity of all the trains. The normal train composition comprises one motor car weighing 32 tons, capable of pulling a weight of about 20-24 tons in trailers on all grades and at normal speed. The motor car has seats for 66 passengers and the trailers for 60-70 more, making a total seating capacity for between 130-140 passengers.

A general view of a motor car is given on Fig. 9. It is a double bogie car with a 64 h.p. three-phase motor geared to each axle. The gear ratio is 1 : 3 and the speed of the motors 600 revolutions per minute, equivalent to a train speed of 39 km. (24.2 miles). The four motors are connected with their stators in parallel. The line current passes first through one of the two controllers, placed one on each car platform, then through automatic cut-outs to the motors. The first motion of the controller handle closes the switch shown on Fig. 10 and connects the stators to the line, at the same time cutting in four

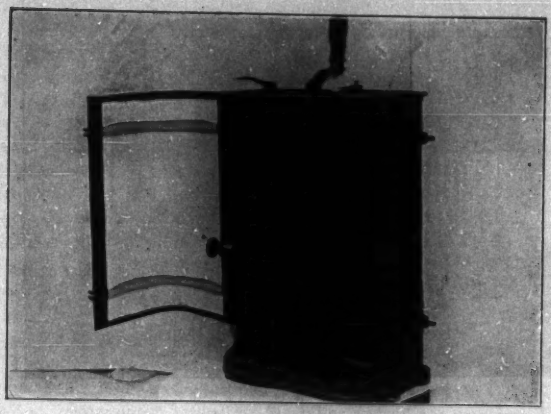


FIG 10.

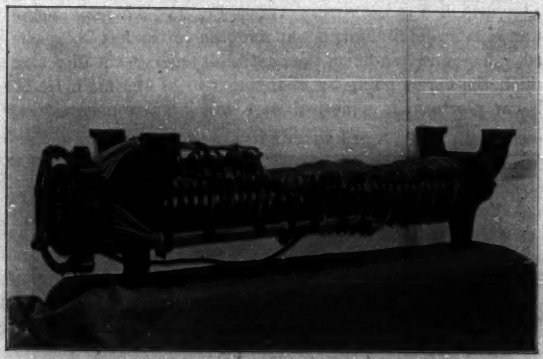


FIG. 11.

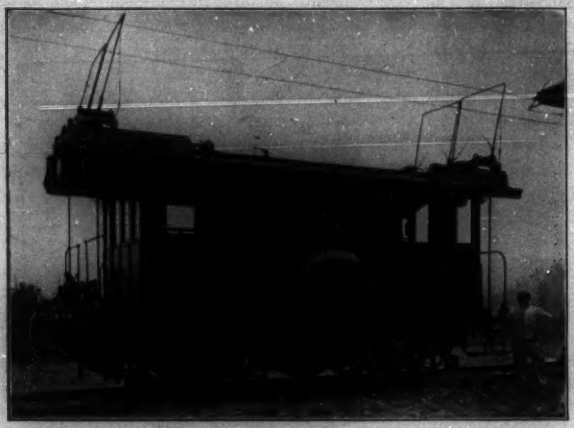


FIG. 12.

rheostats, one into each rotor circuit. Subsequent turning of the controller handle works a combination bevel and chain gear through which three carbon brushes are moved on a sort of commutator attached to each rheostat (see Fig. 11), whereby all the resistance is gradually taken out and the rotors left short-circuited. A second handle on the controller reverses the direction in which the car is going by changing two of the main leads. Each car platform is equipped with two ampere-meters, one

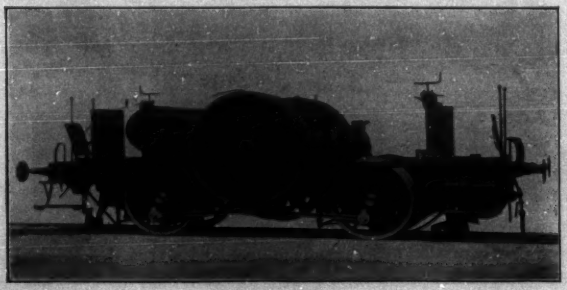


FIG. 13.

voltmeter and a recording tachometer. A Westinghouse brake and an electric lighting and heating installation complete the equipment.

One of the freight locomotives is shown in Figs. 12 and 13. They are designed for a speed of 19½ km. (about 12 miles) per hour, and will haul a weight of 100 tons (not including their own weight) up the steepest grade of 2.5%. The weight of a locomotive complete is 30 tons, equally divided between two axles. Two motors of 150 h.p. each are mounted on a common shaft half way between these two axles and drive by means of a reduction gear first an intermediary axle, and from this axle by means of connecting rods, all four driving wheels. These are 1.23 m. (almost exactly 4 ft.) in diameter. A common rheostat serves for starting both motors and there is a controller on each platform as in the case of the passenger cars. The same measuring instruments are also to be found, as well as a Westinghouse and an additional hand brake.

This railway has now been in successful operation for almost three years. It was equipped by Brown, Boveri & Co., of Baden, Switzerland, as well as the other Swiss lines mentioned. Later on some actual results obtained on this road will be given, but attention is directed first to three experimental lines recently installed for the purpose of ascertaining the conditions met on long trunk lines with higher voltages and very high speeds.

Lecco-Colico-Sondrio-Chiavenna Railway. — In 1901 Ganz & Co. of Budapest finished the electric equipment of what is usually called the Valtellina Railway in the northern part of Italy.

The length of the line from Lecco to Chiavenna is 65 km. (40 miles), the branch from Colico to Sondrio 41 km. (25 miles). The gauge is normal = 1.43 m. The normal speed is 60 km. (37 miles) per hour for passenger trains and 30 km. for freight trains. It is evident that under these conditions it would have been somewhat difficult to handle the traffic with 750 or even 1,000 volts, and it was therefore decided to adopt a higher voltage. Tests made in the Alt-Ofen shipyard near Budapest showed 3,000 volts to be very suitable for the purpose, and this is the line voltage definitely chosen for this road. The power station generates 20,000 volts at 15 cycles per second 12 transformers of 300 k.w. each, along the line about 10 km. from each other, reduce this to 3,000 volts. For short periods these transformers can give three times their normal output with a 6% drop

in voltage. There are two 8 mm. trolley wires, the track serving as a third conductor. The rolling stock shows passenger automobiles weighing 50 tons, and freight locomotives weighing 40 tons each. Both are of the double bogie type, with one motor of 150 h.p. on each of the four driving axles. The motors are mounted direct on hollow shafts on the axles, driving the latter by means of a flexible coupling. For the passenger cars the so-called "cascade" connection is made use of, two of the motors being connected to the 3,000 volts directly, the other two to the 300 volts induced in the rotors of the first two. Thus

FIG. 14.

half normal speed is obtained and a certain economy in starting. The freight locomotives, however, use resistances only for starting purposes.

Fig. 14 shows one of the passenger cars with a trailer. The contact device is of the roller type, two copper rollers 40 cm. long being separated by a piece of hard wood 12 cm. long, saturated with paraffin under pressure. In the interior of the cars the high tension is carried in iron pipes insulated inside and connected to earth. The current enters the stators of the motors after passing a high tension switch placed in a separate chamber. Thus all possible means have been employed to ensure absolute safety to the passengers. Trial runs have been made on this line but several details seem to need to be perfected, and the line is not yet open for traffic.

Tests at Grosslichterfelde.—Still higher voltages were used by Siemens & Halske in 1899 and 1900 during extensive tests made on the Teltower Road between Grosslichterfelde and Zehlendorf on a specially constructed test track a little over one mile long, normal gauge, with curves of 200, 100 and 40 m. radius. On account of the traffic on this public road the contact line had to be placed on one side of the road and for the same reasons a guard wire net had to be fixed under all wires. The main object of these tests was to find a suitable contact device and the best possible line construction to handle a cur-

FIG. 15.

rent of 10,000 volts and at car speeds up to 60 km. (37 miles).

The first tests were made with a device making contact with the line from above, as shown on Fig. 15. The line wire was fastened to triple petticoat porcelain insulators by means of special brass pieces. The insulators were mounted on wooden cross-arms of different lengths which were hinged to iron poles in such a way as to permit the tension in the wires to be equalized without difficulty. The three wires formed an inclined plane as may clearly be seen from the photograph.

Later the line construction was changed and arranged for making contact from the side. The three wires were placed in a vertical plane with distances of about one yard from one

another. The wooden cross-arms were replaced by elliptically curved angle irons provided with a guy wire, to which the insulators were fastened inclined toward the track. The line and the corresponding contact devices are clearly shown in Fig. 16.

In both cases tests were made with line voltages of 750, 2,000

FIG. 16.

and 10,000 volts. The locomotive was fitted with two three-phase induction motors, one on each axle and each for 30 h.p. normal and 120 h.p. maximum output at 650 volts. With 850 volts the output would be increased to 200 h.p. per motor. These motors had interchangeable armatures so that they could

be used for 750 or for 2,000 volts directly with the line voltage. For the tests with 10,000 volts on the line, a transformer was installed on the locomotive to transform down to 750 volts. There were two different reduction gears which could be inserted alternatingly, one for 40 km. an hour, the other for 60 km. an hour. The total weight of the locomotive completely equipped was 16 tons.

From the tests made the following results were deduced:

1. It is entirely feasible to use line voltages up to 10,000 volts and the necessary energy could be taken from the line in each case without difficulty.

2. The contact from the side is rather the better of the two.

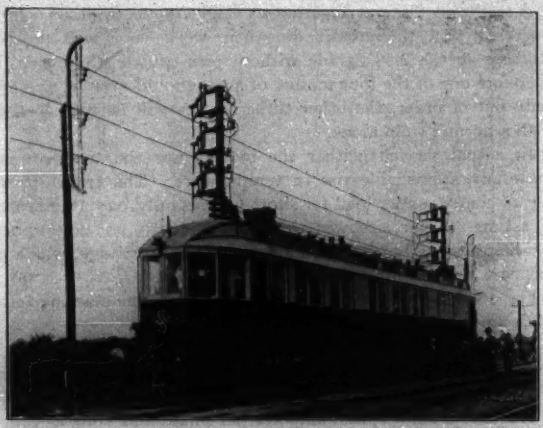


FIG. 17.

The Zossen Railway.—These results were availed of for the tests which are now being made on the normal gauge line from Marienfelde to Zossen, about 15 miles long, where the line voltage is 10,000 volts at 45-50 periods per second and the speeds attempted up to 220 km. (135 miles) an hour.

It would lead too far to go into details regarding these tests which have not yet been completed. Suffice it to say that as far as the electric equipment is concerned, they have been entirely satisfactory. The maximum speed obtained thus far is 160 km. (100 miles) per hour.

Fig. 17 shows one of the cars employed, and it will be noticed that line and contact device are shaped after the models used during the tests carried out on the Teltow road. There are 4 motors per car, each of 250 h.p. normal and 750 h.p. maximum output. The car when completely equipped weighs 90 tons and is designed to take 50 passengers.

Tests on the Burgdorf-Thun Railway.—Following the program laid down at the beginning, some special tests made on the Burgdorf-Thun Railway will be described.

First the overload capacity of the passenger cars was tried. These cars were designed to haul normally a total train weight of 50 tons on all grades at a speed of 39 km. (24 miles) an hour.

A test train was put together to weigh 70 tons total, i. e., 40% overload, and the motors did their work very well indeed, starting on the 2.5% grade without any trouble whatever. If therefore one of the four motors of a car should ever be temporarily out of order, the other three motors will be able to deal with a normal train alone.

In actual service neither the motors nor the transformers show any appreciable rise in temperature. The transformers are, of course, under load for short periods only, say 10 minutes at a time. Their size was therefore evidently not determined by their heating but by the maximum drop in voltage, which in this case was not quite 10%.

Fig. 18 shows in curve form the results of some starting tests made under three different conditions:

(a.) One motor car alone weighing 32 tons,

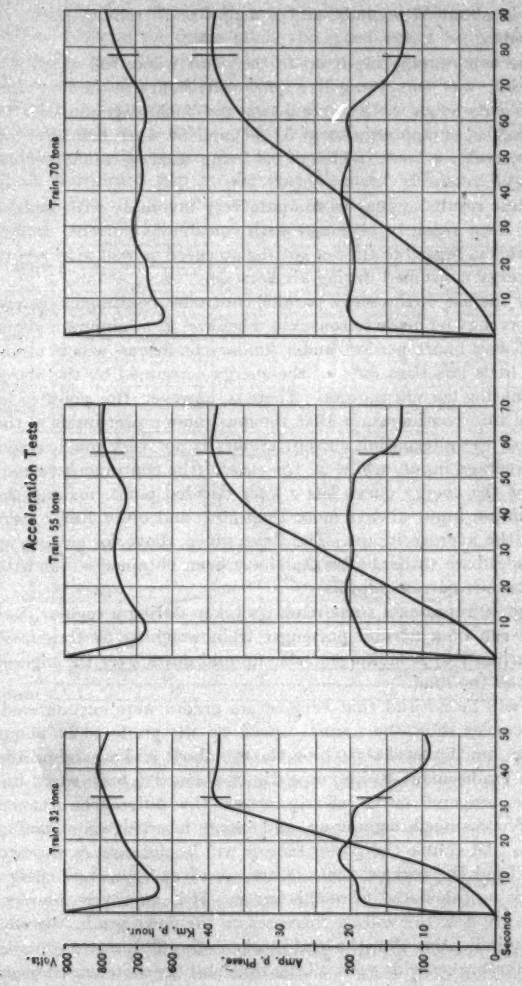
(b.) One motor car hauling 2 trailers, total weight 55 tons.

(c.) One motor car hauling three trailers, total weight 70 tons.

The curves show speed, amperes per phase and volts as functions of time. The tests were made on the level and the controller manipulated so as to keep the current as nearly as possible constant at 200 amperes. This represents actual working conditions.

Readings were taken on the instruments mounted on the car at regular intervals of 5 seconds, the usual employe of the road acting as motorman. The automatic speed record made by the speed indicator corresponded very closely in each case with the curves thus obtained.

It will be found that a weight of 32 tons was brought up to a speed of 24 miles an hour in about 32 seconds, a weight of 55


Acceleration Tests
Train 70 tons
Train 55 tons
Train 33 tons
Volts.
Km. p. hour.
Amp. p. Phase.
Seconds
900
800
700
600
40
30
20
200
100
10
0
10
20
30
40
50
60
70
80
90

tons in about 57 seconds, and a weight of 70 tons in about 78 seconds.

The total energy input up to the point where full speed was reached, was something like 1,600 watt hours in the first case, 3,000 watt hours in the second case and 3,900 watt hours in the third case, or approximately 52, 55 and 56 watt hours per ton respectively, a power factor of 0.8 being used to calculate real energy.

These results appear to compare very favorably with such as have been recently obtained with continuous current motors and this in regard to time of getting up speed as well as in regard to energy consumed during acceleration.

By the use of the series parallel controller, continuous current motors may be made to consume, I believe, as a minimum about 40-45 watt hours per ton under similar conditions, which would be a little less than 80% of the energy consumed by the above alternating current motors. There is, however, this point to be taken into consideration, that the maximum power input in the case of the alternating current motors is not very much above the average input, while in the case of the continuous current motor the energy curve has a very decided point, making the maximum input always more than 50% and often 100% more than the average input. The times given above for getting up full speed are rather better than have been obtained so far with continuous current motors.

Fig. 19 represents some readings taken during a regular time table run of a normal passenger train weighing 50 tons from Walkringen to Konolfingen, viz: up and down over the highest point of the road.

It will be noticed that very severe grades were encountered. The curves show the normal speed up the grade to be about 38 km., on the level stretch on the top about 39 km. and on the down grade about 40 km. or a slip of about 2% both ways.

The amperes curve clearly shows the difference between energy consumed in going up, and energy returned when coming down. Of course the power factors will be different in the two cases, and the real amounts of consumed and returned energy cannot be calculated from this curve. It is, however, interesting to see how the voltage increases on the down grade, thereby clearly indicating that the load is taken off. This test was made with the brakes wide open all the time and the motor resistances were used for starting purposes only.

A further test showed that by inserting resistance in the motors while on the down grade the speed could be increased materially and the speed reached on this occasion was about 44 km. on a down grade of about 1.4%.

Finally a test was made on a fully loaded train which was going up hill on a 2.5% grade. It was suddenly changed to going down. All brakes were left open and yet the train settled on its downward trip at the normal speed of about 40 km.

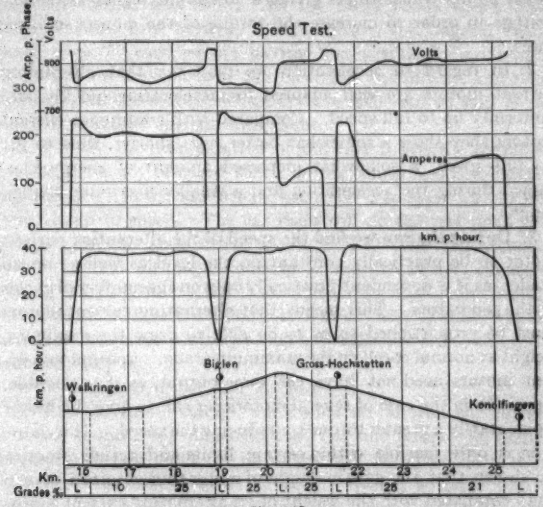


FIG. 19.

which was not exceeded. Then its direction was changed again and the start was made without any difficulty whatever.

Conclusions.—From these tests we may draw some very interesting conclusions.

I shall first sum up the results more especially in regard to the motors and the car equipments, which may be formulated as follows:

1. If properly designed, alternating current motors may be made to start under full load with not more than normal full load running current. They will also start under a considerable

overload. The only condition which has to be strictly observed in the case of alternating current motors is that the drop in the line voltage may not exceed a certain percentage, say 15% to be on the safe side. In this respect the continuous current system is more elastic and a continuous current motor will start with full torque even under very low voltages. In practice there is, however, no reason for allowing excessive drops in the line. Besides it would be easy to install on particularly exposed points transformers giving a somewhat higher secondary voltage in order to increase the torque of the motors in these cases.

2. In regard to acceleration we may say that alternating current motors are well adapted for accelerating quickly and uniformly up to full speed. Compared with continuous current motors they show a somewhat better, viz: shorter, time to get up full speed, a somewhat increased amount of energy consumed during the acceleration and a smaller maximum energy input.

3. During the run we find the speed of the alternating current motor to be practically constant on the level as well as on all grades, as it is dependent practically only on the number of cycles of the generators. This means that alternating current motors must be proportioned so as to be able to draw the maximum weight at normal speed on the maximum grade. Continuous current motors need not have the same output, as it is possible, especially in the case of several motors per car, to give the motor momentarily a greater torque by reducing the speed. This, however, is only feasible within certain limits and actual practice has shown that the gain in weight of motor thus obtained is very small compared with the weight of an alternating current motor running always at the same speed. In most cases it will hardly exceed 10-15%. Besides, as pointed out above, the voltage of the line might be increased at the grades in order to increase the capacity of the alternating current motor.

4. On down grades the alternating current motor acts as a generator returning energy to the line. This recuperation of energy is not only theoretically feasible, but is of actual interest in the case of prolonged down grades where the motors thus automatically brake themselves and where the descending trains greatly relieve the power station. In Siemens & Halske's tests, the alternating current generators were driven by continuous current motors from a storage battery. When the car

was going down grade, energy was returned and the storage battery actually charged. The Swiss mountain lines have installed water resistances to use up the excess of energy made free by descending trains.

5. In a mechanical way the alternating current motor is of course superior to the continuous current motor. The absence of the commutator alone is an advantage. Then the voltage in the rotor may be chosen as low as convenient, which makes the rheostats better and safer. All the Swiss roads which have been operated now between 3 and 4 years, the Lugano Tramways even 7 years, report having had practically no repairs whatever on any parts of the electrical equipment, and none whatever on the motors, which is more than can be said of the usual continuous current equipment.

6. Finally the manipulation of the cars is greatly simplified by the constancy of speed which in this connection is a decided advantage. All the motorman has to do is to start his car and bring it up to speed. The car itself will do the rest until it is stopped by the application of the brake. The concatenated motor control although showing a slightly better efficiency during starting makes the controlling apparatus more complicated and it is therefore preferable in most cases to adhere to the ordinary resistance control, which has really proved to be pretty efficient after all.

Now in regard to the line we find:

7. The increased voltage admissible for alternating current systems reduces the dimensions of the line wires. If carried beyond a certain point the insulation will, however, have to be increased. In cases where the energy used is so large that it cannot be taken off the line at voltages below 1,000 volts, alternating current becomes a necessity. I believe that 100-150 amperes per contact device is just about the maximum permissible, although I know that in some cases, especially in America, as much as 300 amperes have been taken off by one trolley wheel.

8. The transformation of the high voltage alternating currents universally used for transmission on long roads into continuous current means the installation of rotary converter substations. For transformation into alternating currents stationary transformers are used which do not call for any particular attendance and, having no rotating parts, do not show any deterioration from use.

Concluding I might now make the following few general remarks regarding the applicability of the two systems for traction purposes:

Both systems are probably capable of satisfactorily doing the work demanded by any traction problem. I therefore repeat that each case ought to be studied for itself in order to find out which system presents the greater advantages.

Very irregular profile and frequent stops, especially if combined with greatly varying speeds as found for instance in congested city street traffic, make a line generally more suitable for continuous current, while a regular profile, even in the case of steep grades, and long runs between stations, would make it better fitted for alternating currents.

Those cases are rare, however, which allow of an *a priori* decision in this respect, and I believe that a discussion on the merits of the two systems in general is a difficult thing.

What I would like to call your attention to, is the fact that the Burgdorf-Thun Railway answers a whole series of questions relating to the application of three-phase alternating current to electric traction, and proves without doubt the possibility of replacing the present steam locomotives by electrically driven vehicles. This, of course, is of special interest to countries like Switzerland, possessing natural resources in the way of water power, but large coal fields may also be put to better use by erecting electric central stations in their immediate neighborhood and transmitting the energy thus generated electrically to the places where it will be used on the cars.

Zurich, Switzerland, April, 1902.

A paper presented at the Annual Meeting of the American Institute of Electrical Engineers at New York, May 20th, 1902.

A NOVEL COMBINATION OF POLYPHASE MOTORS FOR TRACTION PURPOSES.

BY ERNST DANIELSON.

During the last few years there has been a great deal of discussion as to the possibility of using alternating current motors economically for traction purposes. The result so far obtained seems to be that while these motors may prove successful not only technically but also commercially in special cases, yet as a rule they are inferior to the direct current series motors for general work. The reason for this is that the polyphase motors behave like shunt motors, *i. e.*, operate economically only at a certain speed and that accordingly other speeds are obtained only with a sacrifice in economy. It is true also that the induction motors have other drawbacks, for instance, the wattless currents which necessarily belong to them, but it seems that the advantages which they possess in simplicity and of doing away with sub-stations using rotating machinery, are important enough to compensate for the disadvantage of wattless currents. It has also been pointed out by Mr. Scott at the Buffalo convention when advocating the D. C. motors for electric railway service, that the invention of a speed changing device might change the situation. The author here proposes to deal with an arrangement which makes it possible to obtain economically four different speeds by means of only two motors—an arrangement which it seems will do away with some of the difficulties now experienced in applying the induction motors to railway work.

As is well known the concatenated control of two induction motors consists in connecting the secondary circuit of one to the

primary of the other, mechanical connection being arranged so as to make the moving parts of both motors always run at the same speed. In this way a combination is obtained giving a speed corresponding to half of the regular speed of each motor. The torque of each motor will be the same when used single or in concatenated connection. This means that the output of the concatenated combination is only half of the output of the motors, operating independently. If instead of using two similar motors two motors, of different speeds (*i. e.* with a different number of poles) are combined in concatenated connection, a speed is obtained which corresponds to a number of poles equal to the sum of both motors. Suppose a combination of a 6-pole and a 4-pole motor and that the frequency = 50 cycles per second—then three different speeds are possible, viz: the speed of the 4-pole motor alone (the 6-pole motor running idle)

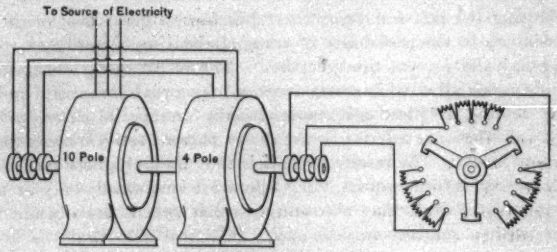


FIG. 1.

= 1500 rev. p. m. (minus slip), the 6-pole motor speed = 1000 rev. p. m. and the combination speed = 600 rev. p. m. If both motors are of the same horse-power, say for instance 50 h.p., it is easy to see that the combination gives also 50 h.p. *By means of this arrangement we have accordingly got a motor capacity of* 50 *h.p. at three different speeds*, 1,500, 1,000 *and* 600 *rev. p. m.*

But it is possible to go still further. When connecting in concatenation we have the possibility of making the connection either so that the torque of both motors works in the same direction or by crossing the leads combining the secondary of the first motor with the primary of the second to get a resultant torque which is the difference between those of the two motors. This arrangement may be called a differential concatenated connection. In order to see the result of this, let us suppose two motors, one with 10 poles and one with four poles, both of the

same output, say 50 h.p. each, the rotors of which are mounted on the same shaft (Fig. 1). If now the source of electricity be connected to the stator of the 4-pole motor, and the rotor winding of the same motor be connected to the rotor winding of the 10-pole motor in such a way that the magnetic field in both rotors will revolve in the same direction relatively to their cores —then the torques of both motors will be opposite to each other. As both motors have the same output, then if the torque of the 4 pole motor be called unity, that of the 10-pole motor will be 7 5, accordingly the resulting torque in this case will be 2.5

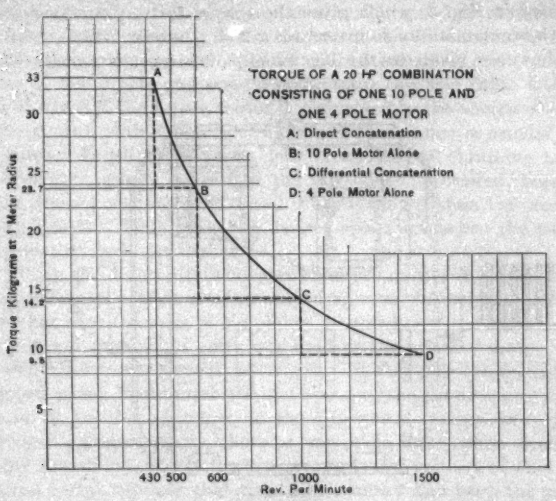


FIG. 2.

– 1 = 1.5 and acting in the same direction as that of the 10-pole motor. As the system begins to move, the frequency in the circuit belonging to the rotors increases, whereas the frequency in the stator of the 10-pole motor decreases. Started in the regular way by inserting resistance in the last secondary and gradually cutting it out, the speed comes up until the frequency in the stator winding of the 10-pole motor approaches zero, which will happen when the speed is 1,000 rev. per minute (the frequency is as before assumed = 50 cycles per second), that is to say we have obtained a motor running at 1000 rev. and

with a torque which is represented by 1.5; the torque of a 1,500 rev. motor (4-pole) of 50 h.p. being equal to 1. Accordingly the horse-power of this arrangement is still 50. By means of this combination of two motors we can thus obtain the same output under the following conditions: (1). The 4-pole motor alone—the 10-pole running idle—speed 1,500 rev. p. m. (2). Differential concatenation speed = 1,000 rev. p. m. (3). 10-pole motor alone—4-pole motor running idle—speed = 600 rev. p. m. (4). Regular or direct concatenation—speed = 428 rev. p. m. These torques and speeds are graphically represented in Fig. 2, which gives the torque for any of the speeds with regular full load current on a 20 h.p. motor. No attention is however given to the lag which, of course, is considerably

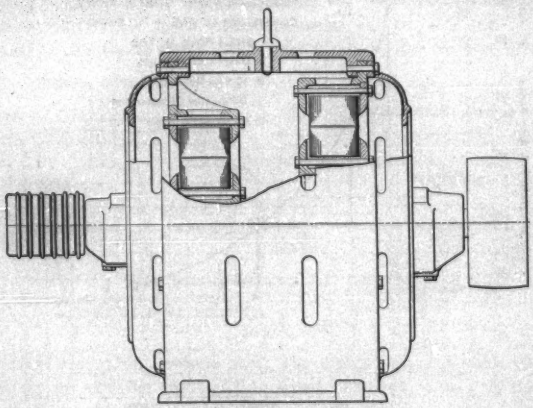


FIG. 3.

greater in the concatenated connection—direct or differential—than with one motor alone.

Fig. 3 shows a small motor built on these principles and which is intended for running tool machinery in a workshop. It is designed with one side 10-pole (large diameter) and the other 4-pole, and accordingly gives the same synchronous speeds 428, 600, 1,000, 1,500.

It goes without saying that if gearing of some kind be used, the motors need not have different numbers of poles; for instance if both motors are identical and are geared to the same shaft so that one gives a speed of 0.617 of what the other gives,

then the speeds which are obtainable form a geometrical series the ratio of which is 0.617; that is to say it is possible to obtain four different speeds each of which is 0.617 of the one which is nearest higher.

Before investigating how this method can be applied for railway motors there should be pointed out some features which are interesting in the differential concatenation. As has been first noticed by Steinmetz a system of two equal motors in concatenated connection can operate at two different speeds, one of them being practically the same as if the motors were driven independently, that is to say, double the speed of the concatenated speed proper. With a system of two unequal motors the same phenomenon appears: a concatenated pair consisting of one 6-pole and one 4-pole motor can also run—with 6-pole speed if the 6-pole motor is connected to the source of electricity and with 4-pole speed if the 4-pole motor is nearest the source. In all these cases there is no risk of obtaining these secondary speeds instead of the one which is desired, because the desired concatenated speed is always lower than the secondary speeds. Thus when the desired speed is reached the motor cannot of itself get higher.

With the differential concatenation the matter is a little more complicated. Above, when describing the differential method we have for the sake of simplicity assumed that the motor with the fewer number of poles was used as the primary motor, *i. e.* connected to the generator circuit. In this case the secondary speed which is obtainable is the speed of the prime motor itself and *in opposite direction to the differential concatenated speed proper*. Consequently there is not even here when starting any possibility of getting the wrong speed instead of that desired. But suppose that the 10-pole motor had been the primary motor. Evidently the starting would take place in the same way as before, but when the speed of 600 rev. was reached the motor would not get up any higher but would continue to run and develop torque as soon as the speed fell a little short of 600 rev. p. m. That, however, also with this connection the differential speed of 1000 rev. (minus slip) works just as well as with the other connection, will be clear from the following:

Suppose that the connections are exactly as before described for differential concatenation only, with the difference that the generator is connected to the stator winding of the 10-pole motor and the rheostat to the stator of the 4-pole motor. If

now the rotating field in the 10-pole motor rotates clockwise and by some external force the machine is speeded up to say 970 rev. p. m. clockwise, what will happen? The magnetic field in the 10-pole rotor moves relatively to the iron core with a speed of $600-970=-370$ rev. p. m., and its direction of rotation accordingly is counter clockwise in the iron. The relative speed of the magnetic field in the 4-pole rotor then is $-370\times10/4$, also counter clockwise. The absolute speed therein is clockwise and equals $970-370\times10/4=45$ rev. p.m. Evidently when this field revolves clockwise—in the same direction as the movement, the 4-pole motor acts as a generator. The action is exactly the same as that of any induction motor with its primary element rotating, running at a higher speed than synchronism. Now the currents from this generator are used to speed up the 10-pole motor. when at the same time evidently the torque required for running the 4-pole generator part of the system is subtracted from the 10-pole motor part. The case is analogous to this: Take a regular induction motor and connect not only its primary but also its secondary to the source of electricity. Then with proper connections we can obtain twice the regular synchronous speed of the motor.

That the 10-pole part of the motor system in this case acts as a motor and not as a generator may be proved in this way. When in an induction motor the speed of the rotor falls short of the synchronous speed, then the current induced in the secondary winding is nearly in phase with the e. m. f. that produces it, that is to say the rotor winding carries what might be called a generator current. If then the rotor increases its speed so as to exceed that of the revolving field of the primary then the electromotive force induced in the secondary part (rotor winding) would change its phase by 180° in relation to the magnetic field; hence it is clear that the current in the secondary winding now has to be in opposition to the phase of the e. m.f. that is to say: in order to make an induction motor work as a motor above synchronism its secondary winding should not itself generate its current but a current has to be let into it against its own e. m. f. This is exactly what happens in one motor here as we have pointed out that the 4-pole side acts as a generator and then of course the e. m. f. from the 10-pole rotor acts as a counter e. m. f.

On account of this we find that also with this connection the motor will act as a motor with $10-4=6$ poles just the same,

but that it will not by itself get up to the right speed but has to be speeded up by some outside force.

Having now described the methods of the differential concatenation in combination with the direct one the next question is this: What advantage can be derived from this arrangement for railway work. Immediately it will be clear to a student of these matters that one advantage of an important nature is the possibility of using economically four different speeds instead of two. (As a matter of fact the method of getting three different speeds has been known for some time but so far as the writer is aware it has not yet been used for traction purposes). When running over a road with considerable grades we now have the possibility of working the motors at different torques

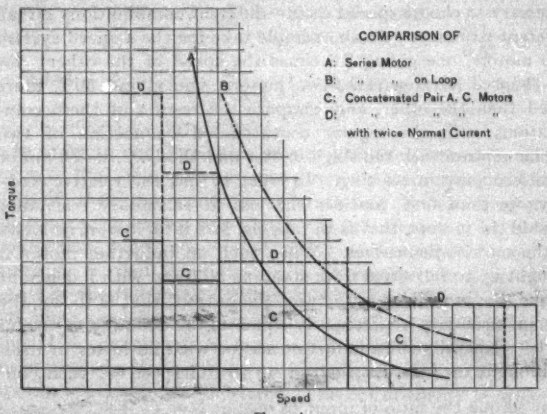


FIG. 4.

corresponding to the different speeds and still have the same output of the motors, *i. e.*, a practically constant current. As is well known this is not the case with the series motor. When this motor increases its speed, not only the torque but also the output becomes less, and can be increased only by cutting out part of the field, an arrangement which is less satisfactory as it often causes a liability of sparking. With the methods described above on the contrary it is possible over almost the whole range to increase the torque above the normal, if that should be considered desirable—for instance in order to make up for lost time. This is shown graphically in Fig. 4, which

shows a curve of torque and speed for a series motor and for a combination of polyphase motors. While the D. C. motor cannot at higher speeds develop torque above the curve "on loop," the A. C. motors can at will momentarily develop anything up to the dotted line. When using this system the task of the motorman will consist only in handling the controller so as to keep the current at a certain normal value not only when accelerating but also when running.

There is, however, one question more, and which is really fully as important as those already dealt with, viz: how is the economy in starting. This is the vital point for a considerable part of traction work projected just now. In order to see the result of the 3 and 4-speed arrangements in this direction, it is necessary to choose special cases—different combinations giving different economy. As an example take for the 4-speed system two motors, one giving 2.5 times the speed of the other; for the 3-speed arrangement, two motors, one giving 50% more speed than the other, and compare the results of these combinations with the regular concatenated connection of two similar motors with the single motor and the D. C. series motor as to economy in starting. In order to find the relative economy we shall first consider the loss in secondary resistance outside the motors, that is to say, the loss if there were no losses in the motors themselves. When such an induction motor is brought up to full speed from standing still and with a constant torque, the input is exactly twice the output, that is to say, the loss in secondary resistance is equal to the amount of useful work. Generally if an induction motor with no losses in itself be brought up from a speed = n up to full speed = 1 with constant torque the ratio of input to output is = $\frac{2}{n+1}$.

Applying this formula to the different cases we find, if the useful work is unity, the input in electrical energy in the different cases:

(1) *The single motor* $\frac{2}{0+1} \times 1 = 2$.

(2) *Two similar motors; concatenated connection used up to half of normal speed:* Energy developed by motor up to half speed = ½; accordingly

$$\frac{2}{0+1} \times \frac{1}{4} + \frac{2}{0.5+1} \times \frac{3}{8} = 1\frac{1}{2}$$

(3) *Two motors with relative speeds* 1 : 1.5; *giving three speeds* 0.4 ; 0.667 ; 1.

Energy stored up at these three speeds = 0.16; 0.444; 1 accordingly

$$\frac{2}{0+1} \times 0.16 + \frac{2}{\frac{0.4}{0.67}+1} \times (0.44 - 0.16) + \frac{2}{0.67+1} \times$$

$$(1 - 0.444) = 0.32 + 0.355 + 0.667 = 1.342.$$

(4) *Two motors with relative speeds* 1; 2.5 *giving four speeds* =0.286; 0.4; 0.667; 1.

Energies corresponding to these speeds
=0.082; 0.16; 0.444; 1.

Input accordingly

$$= \frac{2}{0+1} \times 0.082 + \frac{2}{\frac{0.286}{0.4}+1} \times (0.16 - 0.082) + \frac{2}{\frac{0.4}{0.67}+1} \times$$

$$(0.444 - 0.16) + \frac{2}{0.67+1}(1 - 0.444) = 0.164 + 0.091 +$$

$$+0.355 + 0.667 = 1.277.$$

In order to compare these results with the economy in starting with D. C. motors we assume a series motor having no losses in itself; then the economy, when starting, is depending on at what lowest speed we can obtain the full counter e. m. f. An assumption which corresponds fairly well to regular good engineering is, that the full e. m. f. is reached at a speed of $\frac{2}{3}$ to $\frac{3}{4}$ of the full speed. When connecting the motors in series this will accordingly correspond to a speed of $\frac{1}{9}$ or $\frac{1}{8}$ of full speed when the changing over from series connection to parallel is accomplished. Using the same formula as before which is here equally applicable we find input in electrical energy in order to obtain a useful work of unity:

(1) *Full voltage rendered by the motors at* $\frac{2}{3}$ *of full speed.*
Energy required =

$$\frac{2}{0+1} \times \frac{1}{9} + \frac{2}{\frac{0.333}{0.667}+1} \times \left(\frac{4}{9} - \frac{1}{9}\right) + \left(1 - \frac{4}{9}\right) =$$

$$= 0.222 + 0.444 + 0.555 = 1.222.$$

(2) *Full voltage rendered by the motors at* $\frac{3}{4}$ *of full speed.*
Energy required =

$$\frac{2}{0+1} \times \frac{9}{64} + \frac{2}{\frac{0.375}{0.75}+1} \times \left(\frac{9}{16} - \frac{9}{\ldots}\right) + \left(1 - \frac{9}{16}\right) =$$

$0.281 + 0.562 + 0.437 = 1.281$.

Comparing these results we find that neglecting the losses in the motors themselves, the economy in starting. when using the combination of direct and differential concatenated connection, may be made very nearly the same as in direct current work, and that the three-speed concatenated connection gives an input of something like 6 to 7% more, the regular concatenated connection with 2 similar motors an input of about 20% more than the direct current and 4-speed alternating system and finally the single alternating motor an input of about 75% more.

Now taking into consideration the losses of the motors themselves in order to get a really fair comparison of the relative merits we may assume the efficiency of the series motor and an induction motor at full load the same, say 92%—the efficiency of two motors in concatenation will then come to something like 82% (or even 84 with a low periodicity, say 25 cycles). Let us, however, assume only 82%. If this is taken into considerat'on and the time during which the motors work with their different efficiencies, in different connections is also considered, we get the following results:

Electrical energy for obtaining unity useful work in starting up to full speed

(1) *The single alternating motor* 2.17

(2) *Two similar motors: concatenated connection used up to half of normal speed* = 1.72.

(3) *Two motors with relative speeds* 1 : 1.5, *giving three speeds* $0.4 : 0.667 : 1 = 1.51$.

(4) *Two motors with relative speeds* 1 : 2.5, *giving four speeds:* $0.286 : 0.4 : 0.667 : 1 = 1.45$.

(5) *Continuous current series motors operating in series up to* $\frac{1}{2}$ *of full speed and resistance entirely cut out at* $\frac{3}{4}$ *of full speed* = 1.33.

(6) *Continuous current series motors operating in series up to* $\frac{3}{4}$ *of full speed and resistance entirely cut out at* $\frac{3}{4}$ *of full speed* = 1.4.

In these calculations some factors of minor importance are neglected. Considering for instance the iron losses in the secondary of the induction motors when accelerating would make the figures slightly more favorable to the D. C. series motors. On the contrary, it should be observed that there is an approximation in favor of the series motor to assume that connected

in series they get up to fully half of the speed, when connected in multiple with same current. These approximations, however, will have very small influence on the results obtained.

Now taking into consideration the energy which can be returned to the line by means of the A. C. motors it is evident that also in this respect an advantage is obtained over the simple concatenated connection.

Taking the three-speed combination we find it possible to brake electrically and return energy to about 0.43 of the full speed and with the four-speed combination down to about 0.31 of the same.

Theoretically it would be possible, when braking electrically, with the three and four-speed arrangements to do it in steps, but as this would mean a slower stopping, reference is here only made to applying at once the full braking torque corresponding to the concatenation giving the smallest speed.

(1) *Single motor—no energy.*

(2) *Two similar motors.*

Braking down to about 0.54% speed. Energy restored when braking from speed = n down to the least possible = n_1 with that connection = $\frac{2\,n_1}{n_1 + n} \times$ efficiency of motor acting as generator $\times$ energy taken from moving masses.

When using motors in concatenation for braking it must be borne in mind that it is not generally possible to obtain a negative torque until the speed has come down to a certain percentage of the full speed.[1] This percentage is dependent on the resistances of the conductors and may vary considerably. For the purpose of getting a comparison it is here assumed that the electrical braking can begin at a speed of 0.9 of the synchronous speed.

In this case energy accordingly is taken from moving masses from 0.9 down to 0.54 of full speed. Accordingly if efficiency be taken = 0.82

$$(0.81-0.29)\times\frac{2\times 0.54}{0.54+0.9}\times 0.82 = 0.32$$

(3) *Three-speed motors as before.* When braking, connect immediately in concatenation so as to be able to use the same connection down to 0.43 of full speed.

1. With the three and four-speed arrangements it can be obtained but involves more complication.

$$\text{Energy restored} = (0.81 - 0.185) \times \frac{2 \times 0.43}{0.43 + 0.9} \times 0.82 = 0.33$$

(4) *Four-speed motors as before.* When braking connect directly for being able to brake down to a speed of 0.31 of full speed.

$$\text{Energy restored} = (0.81 - 0.096) \times \frac{2 \times 0.31}{0.31 + 0.9} \times 0.82 = 0.3$$

The results so far obtained would correspond to reality in such cases where gearing is not made use of; if gearing is used, the loss therein should be taken into consideration. This loss may generally be estimated at about 5%; it must however, be borne in mind that in the case of differential concatenation it may amount to somewhat more, since the power transmitted through the gearing really is more than the resultant power. In the

RELATIVE AMOUNT OF ENERGY CONSUMED.

	Accelerating only.		Accelerating and Electrically Braking.	
	Without gearing.	With gearing.	Without gearing.	With gearing.
D. C. Motor, resistance entirely cut out at 2/3 full speed	1.33	1.4	1.33	1.4
D. C. Motor, resistance entirely cut out at ½ full speed	1.4	1.48	1.4	1.48
A. C. Motor, simple	2.17	2.29	2.17	2.29
A. C. Motors regular concatenated connection	1.68	1.77	1.36	1.47
A. C. Motors, three speeds: 0.4 : 0.67 : 1	1.5	1.58	1.17	1.27
A. C. Motors, four speeds: 0.285 : 0.4 : 0.67 : 1	1.45	1.52	1.15	1.24

table below where the results are brought together this increased loss is, however, neglected. The table gives a comparison of the different systems as to input, the motors for starting up to full speed and electrically braking down as far as possible.

Admitting that the polyphase motor as a rule is fully as efficient as the series D. C. motor, it may be considered that when working on an even road the difference in energy consumption will be negligible, then it would appear that by using the four-speed arrangements of concatenated connection it would be possible to get a more economical method of working electric roads than by means of the D. C. system with series motors. Considering at the same time that for greater distances the electric energy has to be generated as alternating current and then transformed into direct in converter stations,

whereas with polyphase motors on the cars simply static transformers can be used giving a difference in loss of at least 5% to 7% in favor of the alternating current motors, the comparison comes out still more in favor of these. An advantage also for them is that there is no need for high voltage in the rotating parts of the motors; the rotor windings may be arranged for any desired voltage thus giving the designer full liberty to choose this so as to get the most convenient winding.

The author is fully aware of the drawbacks inherent to the alternating system such as the necessity of using a double trolley, the lag, etc., and admits that in many cases this system is entirely out of question, for instance, only on account of the double trolley, but for elevated roads and for underground work this matter hardly comes into consideration, and in many other cases the drawbacks of the alternating system will probably be more than balanced by its greater economy.

One thing more should be mentioned. Probably it will be pointed out that there will be difficulties introduced by making one of the motors of 2.5 times the torque of the other. To this the author would reply that the best solution probably in many cases will be to connect in concatenation one motor with two or three others in parallel—for instance with a locomotive with four axles, have three of the motors of a slower running type than the fourth, and of a current carrying capacity something like $\frac{1}{3}$ of this one. The same arrangement could be used for an ordinary double-truck car with four motors. For cars with only two axles the best arrangement will probably be with only three-speed connection, and then there will be very little difficulty—the difference in torque of the two motors not being so considerable.

WESTERAS, SWEDEN, Oct. 25, 1901.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

NEW YORK, Jan. 3, 1902.

The 159th meeting of the INSTITUTE was called to order at 8.25 P. M., President Charles P. Steinmetz in the Chair.

SECRETARY POPE:—At the meeting of the Board of Directors this afternoon, the following associates were elected:

NAME.	ADDRESS.	ENDORSED BY
AMSTUTZ, NOAH STEINER,	Business partner Amstutz Osborn Co., 27 Hillsdale Ave., Cleveland, Ohio.	E. P. Roberts. Geo. M. Hoag. Alfred H. Cowles.
ARMSTRONG, SAMUEL GEORGE,	1 Kimberley Villa, Harrington St., Cape Town, South Africa.	J. E. Lloyd. Geo. W. Blodgett. John Denham.
ARNOLD, CHESTER HASTINGS,	Assistant Engineer New York Telephone Co., 18 Cortlandt St.; residence, 241 East 18th St., New York City.	C. A. Adams, Jr. B. Gherardi, Jr. H. F. Thurber.
AVERRETT, ANDREW E.,	Engineer, General Electric Co., Schenectady, N. Y.	C. P. Steinmetz. W. I. Slichter. Eskil Berg.
ERWIN, FRANK BENNETT,	Demonstrator Federal Instrument Co., 293 Clinton Ave., Albany, N. Y.	G. C. Van Buren. E. G. Bernard. R. J. Pratt.
ESTES, ORANGE A.,	Central Union Telephone Co., Akron, Ohio.	J. H. Klinck. G. F. Sever. Henry Rustin.
EVERIT, EDWARD HOTCHKISS,	Superintendent of Equipment, The So. N. E. Telephone Co., 641 Whitney Ave., New Haven, Conn.	E. F. Peck. C. W. Price. E. R. Knowles.
FERGUSON, SAMUEL,	Engineer, General Electric Co., Schenectady, N. Y.	C. P. Steinmetz. A. H. Kruesi. M. I. Pupin.
FITZGERALD, THOMAS, JR.,	Superintendent F. C. E. R. R. Co., Fairmount, W. Va.	Louis Duncan. W. L. Hodges. W. D. Young.
GRAY, EDWARD WYLLYS TAYLOR,	Manager, New York Sales Office, Westinghouse Electric and Mfg. Co., 120 Broadway, New York City; residence, Montclair, N. J.	C. W. Rice. C. F. Scott. C. A. Terry.

HANKS, MARSHALL WILFRED, Engineer, Nernst Lamp Co.; residence, Amber Club, Pittsburg, Pa.	C. F. Scott. A. J. Wurts. M. C. Beebe.
HENRY, GEORGE CLINTON, Assistant to President, The Johnson Law Co.; 51 W. Forsythe St., Jacksonville, Fla.	A. M. Schoen. F. E. Idell. C. S. Hammatt.
HERZOG, JOSEF, Chief of Installations Department, Ganz & Co., V. Elisabetplatz 1, Budapest, Hungary.	Francis Jehl. Johann Sahulka. Carl Hering.
HILLMAN, HARRY W., General Electric Co., Schenectady, N. Y.	C. P. Steinmetz. C. W. Rice. H. G. Reist.
HUTCHINSON, ROLIN WILLIAM, JR., Student, Polytechnic Institute; residence, 302 Clinton St., Brooklyn, N. Y.	Saml. Sheldon. Hobart Mason. Sidney W. Ashe.
KERR, SAMUEL ROSS, Foreman in Testing Department Triumph Electric Co., 610 Baymiller St.; residence, 616 West 8th St., Cincinnati, Ohio.	C. S. Reno. F. E. Kinsman. Ralph W. Pope.
KERSHNER, JEFFERSON E., Consulting Engineer, The Lancaster R. & L. Co., Lancaster, Pa.	C. A. Bragg. C. I. Young. C. F. Scott.
KLINE, JAMES JOSEPH, Engineering Student, Stanley Electric Mfg. Co.; residence, Beech Grove Inn, Pittsfield, Mass.	C. L. Cory. C. O. Poole. D. B. Rushmore.
LAMB, FRANCIS JOSEPH, Electrical Engineer, Lamb & Co., cor Kent and Lyon Sts., Grand Rapids, Mich.	G. H. Guy. T. C. Martin. Max Loewenthal
LAYTON, GORDON, Electrical Engineer, British Westinghouse E. & M. Co.; residence, 48 Lancaster Park, Richmond, England, 327 Pitt St., Wilkinsburg, Pa.	C. F. Scott. C. E. Skinner. H. P. Davis.
MAXIM, HIRAM PERCY, Engineer, Vehicle Motor Department, Westinghouse E. & M. Co., Pittsburg, Pa.	C. F. Scott. Elihu Thomson. E. A. Sperry.
MCCARTHY, ALBION FULLER, Inspector New York Edison Co., 23 Manhasset Place, Brooklyn, N. Y.	J. W. Lieb, Jr. Arthur Williams. T. Wolcott.
NEWELL, FRANK CLARENCE, Consulting Electrical Engineer, Westinghouse Air Brake Co.; residence, 526 Wallace Ave., Wilkinsburg, Pa.	C. F. Scott. C. B. Auel. C. E. Skinner.
PRATT, WILLIAM HEMMENWAY, Designing Engineer, General Electric Co.; residence, 60 Eastern Ave., Lynn Mass.	Elihu Thomson. C. P. Steinmetz. W. C. Fish.
RAMSON ALLEN EDWARD, Engineer and Salesman, W. E. & Mfg. Co., 314 Occidental Ave., Seattle, Wash.	C. F. Scott. W. K. Dunlap. P. H. Thomas.
REILLY, HARRY WINNE, J. G. White & Co., Monroe, Mich.	H. A. Lardner. D. C. Jackson. C. W. Rice.

SHUSTER, JOHN WESLEY, Instructor in Electrical Engineering, University of Wisconsin; residence, 18 E. Dayton St., Madison, Wis.	D. C. Jackson. B. V. Swenson. B. Frankenfield.
SZUK, GEZA, Chief Engineer, Ganz & Co.; residence, Csalogany utcza 52 Budapest II, Hungary.	Francis Jehl. Johann Sahulka. Carl Hering.
TAYLOR, FRANK H., Westinghouse Electric and Mfg. Co.; residence, 7422 Penn Ave., Pittsburg, Pa.	C. F. Scott. Ph. Lange. Calvert Townley.
TREAT, ROBERT BELDEN, Electrical Engineer, Crocker Wheeler Co., Ampere, N. J.; residence, 43 South 10th St., Newark, N. J.	G. S. Dunn. W. E. Goldsborough. C. P. Matthews.
VANKIRK, EDWARD POWER, Electrical Engineer, Westinghouse Air Brake Co., Elizabeth, Pa.	C. F. Scott. C. B. Auel. C. A. Bragg.
WEBSTER, WALTER COATES, Assistant to 4th Vice-President Westingohuse Electric and Mfg. Co., 120 Broadway. New York City.	C. A. Terry. C. F. Scott. C. I. Young.
WHITTEMORE, GEORGE W., Engineer Bell Telephone Co.; residence, 24 W. Seneca St., Buffalo, N. Y.	F. A. Pickernell. M. I. Pupin. H. E. Hayes.
ZURFLUH, WILLIAM NICHOLAS, Superintendent, Home Light, Power & Heat Co., Room 11, Arcade Building, Springfield, Ohio.	B. L. Baldwin. B. F. Thomas. F. C. Caldwell.

Total, 34.

Discussion.

President Steinmetz:—Gentlemen, the topic of to-night's discussion is "Light and Methods of Illumination." The problem of producing light consists of transforming some form of energy into radiation within that range of wave length which exerts the physiological effect of visibility. Light, therefore, is a physiological and not a physical quantity, and therein lie most of the difficulties in comparing and measuring light and reducing the unit of light to mechanical units.

Until the latter part of the last century all the methods of producing artificial light had been based on combustion; that is, transformation of chemical energy into light. With the advance of electrical engineering the transformation of electrical energy into light has been introduced. Neither of these transformations, however, is direct, but from heat as an intermediary form of energy, and therefore, owing to the inherent character of heat as low grade energy or irregular motion, the efficiency of such transformation must be very low. An essential increase in the efficiency of light production can, therefore, be found only by devising some direct transformation of electrical energy into light energy, without the intermediary of heat.

The means for producing light used heretofore, or proposed, are incandescence, heat luminescence and electro-luminescence.

If heat energy is communicated to a solid body, with increase of temperature the body sends out radiations, the intensity of those radiations increasing with the temperature and the average wave lengths decreasing with the increase of temperature. When a certain temperature is reached, radiations begin to appear within the visible range and the body becomes incandescent. With increasing temperature, the average or mean wave length decreases, and the percentage of visible radiation, therefore, increases; that is, the efficiency of light production increases. This efficiency, however, is limited by the limit of temperature feasible. This limiting temperature is the boiling temperature of the most refractory body, which appears to be carbon.

In the production of light, we have to distinguish between total efficiency, as ratio of energy output in the form of radiation within the range of visibility to total energy input, and radiation efficiency, as ratio of the energy of visible radiation to total radiation. These two efficiencies differ by the energy lost by heat conduction, convection by air currents, etc. In the incandescent lamp this loss of energy is small, and the total efficiency practically equal to the radiation efficiency, but the radiation efficiency is lower, due to the necessity of keeping the filament temperature sufficiently below the boiling point of carbon to secure the desired length of life. In the arc lamp, owing to the crater being at the temperature of the boiling point of carbon, the radiation efficiency is the highest which can be reached, but is still very low, and the total efficiency differs considerably from the

radiation efficiency, especially with smaller units of light. An increase of the radiation efficiency could be secured only if a body more refractory than carbon could be found, and this is not probable. Osmium, if at all more refractory than carbon, which is questionable, does not differ sufficiently to effect a considerable increase of radiation efficiency, and is, besides, excluded from extended use by its very limited existence. Carbides, as far as known, melt in the electric arc, hence are less refractory than carbon. It thus follows that with the carbon arc and incandescent lamp, the limits of efficiency of light production by incandescence have been approached so nearly that an essential increase cannot be expected.

Some solid substances, mainly metallic oxides, however, have an abnormal radiation at some intermediate but fairly high temperature. That is, the percentage of visible radiation emitted by these bodies, and thereby their radiation efficiency is greater than corresponds to the temperature, and therefore as transformers of heat energy into light they are more efficient. This phenomenon may properly be called *heat luminescence* and has been utilized successfully in the incandescent gas light, the Welsbach burner, and is being introduced in the pyro-electrolytic lamp, commonly called the Nernst lamp.

It is very questionable, however, whether thereby an essential increase of efficiency can be secured in electric lighting, since the gain due to the abnormal radiation efficiency is more or less lost by the necessity of operating at a temperature below the fusion point of the pyro-electrolyte, thus considerably below the temperature of the carbon arc.

The different methods of more or less direct transformation of electrical energy into radiation may be combined under the name "Electro-luminescence." Under electrical excitation, non-conducting gases in a vacuum, under high electric stress but with small volume of current, are set in faintly luminous vibration and so give light in the Geissler tube. Metallic vapors at moderate electric pressures, when passing considerable volumes of current become luminous, whether in a vacuum or at atmospheric pressure in air or in an enclosed space, and give a luminous arc. Solid substances in a very high vacuum, under electro-static bombardment send out light.

The Geissler tube as a source of light has the objection of very low intrinsic brilliancy, and probably also very low efficiency, if not very high and commercially impracticable frequencies are employed. Molecular bombardment has the objection of requiring excessive voltages, and especially of exerting a mechanically destructive effect upon the enclosing vessel. A prospect of improvement of the efficiency of electric lighting thus appears only in the direction of the luminous arc, either in vacuo or at atmospheric pressure. The light of the luminous arc and also the Geissler tube is monochromatic, that is, the radiation does not follow the temperature law, but the radiation efficiency is

practically independent of the temperature, and the radiation takes place only at some definite wave length, corresponding to the spectrum lines. The radiation efficiency then is the ratio of the energy of the spectrum lines in the visible range to that of all the spectrum lines, and if most of the intense spectrum lines of a substance lie in the visible range, this substance will give a very high radiation efficiency, independent of the temperature. In addition thereto, however, the spectrum lines should be distributed over the whole range of the visible spectrum, so as to give a fair color to the light.

So far, no electric lamp utilizing a luminous arc has been sufficiently developed to be in commercial use, and the difficulties encountered in this problem are very great.

Now, after this introduction I give the floor to Dr. Louis Bell, for his paper on "Methods of Illumination." I may state that I have been instructed by the Committee on Papers that owing to the number of papers and the discussion which we expect, the time given to each reader of a paper must be strictly limited, and ten minutes will be given for the author of each paper to abstract his paper, and twenty minutes to Dr. Bell, as the reader of the fundamental paper.

Dr. Bell gave an abstract of his paper. [See Feb. 1902, p. 93.]

PRESIDENT STEINMETZ:—Gentlemen, according to our present custom we will postpone the discussion of Dr. Bell's paper until after the reading of the other papers. I will call now upon Mr. W. D'A. Ryan for his paper on "Illumination and Units of Light," as dealing with a problem similar in its characteristics to some parts of Dr. Bell's paper.

Mr. Ryan presented his paper. [See Dec. 1901, p. 909.]

PRESIDENT STEINMETZ:—Gentlemen, you have listened to a very interesting paper, in which Mr. Ryan has brought out very forcibly that it is not the total volume of light, but its distribution, which is of practical importance in the problem of illumination. The next paper by Mr. S. Everett Doane deals with the same problem, although he arrives at a very different conclusion. I therefore call upon Mr. Doane to give his side of the question.

Mr. Doane presented his paper.

PRESIDENT STEINMETZ:—Gentlemen, I can concur in some statements of the last speaker. I had the same experience—not from an automobile, but from a bicycle last summer—that the only way to find the road in a suburban district where it was illuminated by arc lamps was to watch the reflection from the railroad track. Regarding the advantage of distributing by incandescent lamps, I had some experience, also. I tried to light my greenhouse, about a thousand square feet in area, by twenty-five incandescent lamps, well distributed. The meter was recording power, but I could not read by the light. I had to supplement it by putting in another horse power in one large unit of arc lamp, which gave satisfaction. In this case, there was no reflected light, the walls being all glass. Knowing the

undesirability of one large unit of light and the harsh shadows it casts, I still put one arc lamp in one large room in my laboratory, and got a strong, well-distributed illumination. But here the walls were painted brilliantly white. That leads me to the point I desired to bring out, since it is not very thoroughly brought out in the papers, the effect of the surroundings on the distribution of illumination. In a city street with houses on both sides, reflecting a very large amount of light, probably more than the direct light, very few large units may give fairly satisfactory illumination. But on a suburban road with no houses, large units of light mean more or less illuminating the universe, and not the road which we want illuminated. We have drifted in these papers toward the arc lamp, and I now call on Mr. Howell to read his paper on "The Incandescent Lamp of To-day." [See Dec. 1901, p. 923.]

Mr. John W. Howell read his paper, supplementing it by the following remarks:

"Mr. Steinmetz has spoken of the selective radiation of certain of the rare earth oxides in reference to the efficiency of lights, and has quoted the Welsbach mantle and the Nernst lamp as illustrations of the use of materials which give more light at a given temperature than carbon for example. The Nernst lamp interested me very greatly when it appeared. I wanted to see whether the Nernst lamp had a selective radiation and would give a larger amount of light at a given temperature than we would expect from analogy with the carbon filament, and I find that it does not. The filament of a Nernst lamp has only 6/10 the amount of surface that carbon has at the same efficiency in watts per candle, which is a rather surprising result. It indicates that the lamp is operated at a very high temperature and gets the color of its light, which is its most valuable characteristic, from the very high temperature at which it is operated, and not, I believe, from any selective radiation or from any more radiation at a given temperature than we would expect if it were carbon."

PRESIDENT STEINMETZ:—Gentlemen, as very well brought out in Mr. Howell's paper, it is the extreme simplicity of the incandescent lamp which is its most satisfactory feature, and which gives it a superiority over all these new illuminants, no matter how high their efficiency. The great value of simplicity you can best realize when watching the actual use of the incandescent lamps in those places where no special effort is made to replace them. You will find the average use of the lamp is far longer than permissible, and lamps are practically never replaced except when burnt out. That is, the average customer rather than replace the lamp, pays twice as much for the light. I now call upon Dr. C. H. Sharp to abstract his two papers dealing with the question of "Standard of Light" and "An Acetylene-in-Oxygen Flame" as proposed as a means of giving a primary standard of light. [927 and 931.

Dr. Sharp gave an abstract of his papers. [See Dec. 1901, pp.

PRESIDENT STEINMETZ:—The next paper on the program deals with a light of the future, a light differing from the incandescent lamp as much in efficiency as it differs in color. It is a real arc light; that is, a lamp in which the light is given by the electric arc, while that which we have heretofore called an electric arc lamp is not so much an arc, as an incandescent lamp, since the light of the carbon arc lamp is mostly given by the incandescent crater of the carbon, and the arc stream contributes very little to the light. I call upon Mr. P. C. Hewitt to give an abstract of his very interesting paper.

Mr. Hewitt presented his paper. [See Dec. 1901; p. 935.]

PRESIDENT STEINMETZ:—Gentlemen, we have listened to a very interesting paper, outlining the direction in which future work to develop a more efficient means of illumination may proceed. As you have noticed, this lamp requires a practically constant voltage, independent of the current, which means that a steadying resistance would have to be inserted in series to it, just as with the ordinary arc lamp. As I understand, these lamps are operated on continuous current here. I may add that in some experiments we made with this lamp we did succeed in starting the lamp at the voltage at which it was operated without inducing a higher voltage.

The next paper on the program is by Mr. Hammer, who has kindly agreed to discuss a number of interesting features referring to what I have combined under the head of electro-luminescence, phenomena which may lead to improvements in the methods of transformation of electrical energy into light. I give the floor to Mr. Hammer.

Mr. Hammer presented his paper.

PRESIDENT STEINMETZ:—Gentlemen. I believe you will agree with me that we have listened to a series of very interesting papers and discussion is now in order. I call on Mr. Lieb to start the discussion.

MR. J. W. LIEB, JR.:—Mr. President, I am not prepared to make any remarks on the general field covered in these several papers, but I would like to say just a few words that may be of interest to the members generally, in connection with Dr. Sharp's paper, and a reference in the paper by Dr. Bell to standards of illumination. The standard of candle power on which most of the lamps are being manufactured to-day was practically derived from standards imported some ten years ago from the Reichsanstalt. Some few months ago it was desired to check the standards in use generally to-day for the manufacture and sale of incandescent lamps in the United States, to see how closely they agreed with the best standards in use abroad. A number of incandescent lamps that had been carefully standardized and compared with the standards in use in this country, were sent to the Reichsanstalt with the request that the lamps be standardized by placing them in a given position on the photometer, and when giving sixteen candle power, readings be taken of volts and amperes.

Word was received from the Reichsanstalt that they were not prepared to issue standards based upon the British standard candle; their photometric measurements could be issued only in terms of the Hefner amyl-acetate standard. The lamps sent were compared with that standard and the results were communicated to us a few days ago. On comparing the lamps returned, it was found that the photometric value of the lamps representing the standards in general use in this country was within two per cent. of the value assigned by the Reichsanstalt. That is only a preliminary measurement but it is comforting to know that even in the case of such an indefinite standard as the standard of light in commercial use we are progressing very satisfactorily, and that photometric standards in use in different parts of the world on comparison come within such a small limit of error, notwithstanding the fact that a transition coefficient had to be used to make the comparison in terms of the British standard candle. I thought these facts might be of interest in connection with the reference to standards of light in the papers of Prof. Sharp and Dr. Bell.

DR. A. E. WOLFF:—I would like to ask Mr. Lieb whether allowance was made for the fact that the volt as defined in Germany is different from the volt as defined in this country. The Germans adopt 1.4328 volts as the electromotive force of a Clark cell, while in the United States it is legally defined as 1.434 volts. This difference would cause a difference of over 0.5% in the candle-power.

MR. LIEB:—The difference in the standard volt would hardly affect these preliminary measurements, but Dr. Sharp assures me that it has been taken into account.

Dr. A. E. KENNELLY:—The only point that I might mention particularly was the reference of Dr. Bell to the amperes used by the open arc as compared with the enclosed arc lamp. The question of the comparative number of amperes can not be discussed at all. It is altogether a question of energy. When he admits that a 7½ ampere enclosed arc is the equivalent of a 2,000 candle open arc, it is rather a frank admission that for equal energy the arc, everything considered, is equally efficient in either case, which is quite the fact. So far as the color of the arc is concerned practically, it has little bearing on the matter. If we keep within a certain limit of voltage for a direct current arc, say 80 or possibly 90, and for alternating 75 to 80, the purple rays are easily taken care of by selecting suitable glass for the enclosing globe. A clear glass globe will give a very pronounced purple effect, even after it becomes coated with a deposit from the carbon. With what we call an opalescent glass this purple radiation is very largely cut out. That can be very easily proved by throwing a spectrum on the screen and interposing a section of one of the globes which I have in mind. It may very readily be seen how the blue end of the spectrum is cut down and the red end is practically not touched.

DR. LOUIS BELL:—With reference to the alleged admission, I certainly admitted nothing of the kind in regard to the efficiency of the lamps. On the contrary, I am prepared to reiterate that all the evidence that has been obtained by scientific photometry goes to show that the alternating arc, so far as the alternating enclosed arc is concerned, is considerably less efficient than the direct current open arc. An immense mass of data has been accumulated by experimenters on this side of the water and the other, and it is absolutely concurrent so far as the laboratory determinations have gone. What I did say, and what I feel very sure of, is that as a practical illuminant in the street the 7½ ampere enclosed alternating arc is fully equivalent to a 2,000 candle power open arc. That is a very different matter from making any statement that the efficiency of the two is equal, because I know, and anybody who has ever put them on the photometer knows, that you have less efficiency in the alternating arc by reason of the lower temperature at the mouth of the crater. The fact is, however, that as actual radiants on the street they are practically on a par. For instance, on the Boulevard, where I happen to live, they replaced the 2,000 candle power open arc lamp by the 7½ ampere alternating arc, and the result was distinctly good in illumination. On the other hand, I have seen various attempts to replace the 2,000 candle power open arc by a 6½ or a 6¾ ampere alternating arc, and the alternating arc was perceptibly inferior. It is when the energy is pushed up that the latter gains in its relative brilliancy, and then it does not come to the same efficiency, but gives a much better distribution, thanks to the absence of the very crater on which the efficiency of the direct current arc depends. As to color, I will gladly bear him out that it is possible by suitable absorbing media to correct the color of the alternating arc. But, nevertheless, it is not as a matter of fact so corrected in any place I have ever seen, and I have seen them in a great many cases. It may be possible to do it, doubtless it is possible. Theoretically it must be. But, as a matter of practice, the lights do not have their color so corrected within a very long distance. They are very far from being white in color, and that I think is probably attributable to the fact that it is almost impossible to get proper care taken of any arc lamp. The result is that the voltage wanders up and down. You find almost from 59 to 90 volts.

DR. C. A. DOREMUS:—In connection with Dr. Sharp's paper, one or two historical facts may not be out of place. We owe the original oxy-hydrogen lime light to Dr. Hare of Philadelphia. In 1867 Tessie du Motay discovered and showed at the Paris Exposition a method of preparing oxygen on a large scale. He substituted magnesia, afterward zirconia pencils for the lime. The process was brought to this city in 1868, and oxygen was made on a large scale. A double piping system was carried from Forty-fourth Street down to Union Square. The oxygen was introduced also in Buffalo and there a carburetted street gas

was substituted for the pencil. Burners were constructed with a stop-cock, by turning which both gas supplies were regulated; so that if on turning on the gases they did not burn properly, merely turning the stop-cock would bring the amount of the gas and the amount of oxygen to a proper proportion, and a very beautiful light was had. We have at the City College a number of such burners, which date from 1868. Despite the fact that the process worked well on a large scale, circumstances prevented it from being commercially successful in this country. The processes of Brin Bros. and of Mallet make oxygen very cheaply, and recently the fractional distillation of liquid air promises to give us oxygen, the most abundant of all the elements, at a very reasonable cost. So that the future of oxygen illumination in connection either with acetylene or with carburetted gas or with the refractory earths is perhaps as good a one as that of electric illumination.

MR. S. E. DOANE:—There is an interesting matter referred to in Dr. Sharp's paper. The Doctor says: "Photometric comparisons . . . are misleading in that they do not give to the whiter sources credit for the greater visual acuity per candle power which is their due."

In comparing lamps of four watts and three watts per candle, some time ago, it came to my attention (Dr. Sharp and I investigated it later to a small extent) that in the ordinary Bunsen photometer the absorption of light in the paraffin grease spot depends in part upon the color of the light, so that a three-watt lamp, for illustration, in comparison with a four-watt, gives more candles than the photometer indicates.

MR. GEORGE T. HANCHETT:—I had expected that this discussion would bring out numerous methods of distributing light so as to keep the intense radiants from falling directly on the eye. Dr. Bell has dwelt upon this very strongly in his paper, and others have mentioned it also, and I think perhaps it would be of interest to speak regarding an opportunity that I had of witnessing an experiment of this character. It occurred at the Goff Braid Works at Providence, R. I. Mr. Goff, who is an enthusiastic investigator of lighting problems, equipped one of his rooms, which was supplied with spinning machinery, with about ten arc lights. They were the old-fashioned direct-current series type. The current was sent through them in the reverse direction so as to have them burn upside down, thereby throwing the greater portion of their light against the ceiling. Underneath these lamps were placed conical reflectors which entirely hid the arc from any one standing on the floor, and the lamps were placed, I should think, about six feet from the ceiling. The ceiling and walls of the room were painted white with a slight yellow tint. The result was very marked indeed. There were absolutely no shadows in the room and, even underneath the spinning machinery one could see to pick up a small screw or object of any kind, and although the impression after looking

first at the lights and then at the floor was that of darkness, by waiting a moment for the iris to adjust itself, one could see to read perfectly in any part of the room.

DR. BELL:—With reference to the very interesting account of that inverted arc method of illuminating which has been tried not infrequently and always with rather successful results, there is one thing you want to watch out for,and that is not to get rid of your shadows too completely, if there is any detail work to be done, where the absence of shadows bothers you. We locate things in space by the light and shade effects. If you get the shade completely out of the way by uniform diffusion over a very large space, it is apt to bother vision quite a little. In fact, I have known one or two instances where draughtsmen complained bitterly of the lack of shadows. But if the lights thus thrown upward are placed a little off to one side or if the construction of the room is such that the diffused light is a little dissymmetrical, that difficulty would be obviated.

PRESIDENT STEINMETZ:—A similar method of diffusing light, at least on the same general principle, I remember was used quite extensively about ten years ago in Europe, by inverting the continuous current arc so as to have the crater on the lower part. There was a large white shade above the lamp, so as to reflect the light immediately from the shade. The luminous radiant now is not the arc but is the shade which receives most of the light from the arc and reflects it. There have been in the last weeks and months various other illuminants proposed, for instance, arc lamps in which materials have been introduced in the arc, as the Bremer lamp, producing luminosity of the arc proper and thereby increasing the efficiency, as claimed, enormously. Perhaps some of you have experimented with this and can enlighten us,and thereby contribute to the facts available in this discussion.

DR. BELL:—I have nothing to add except possibly a single note on the question of selective radiation that has been raised as between carbon, oxides of the rare earths, and a few other substances. The number of substances which give a really selective radiation within the visible spectrum to any considerable extent is very limited. There is some selective radiation in a general way from the material of which the Welsbach burners are made, largely thoria, but the only substances which give markedly selective radiation when heated to a high temperature are erbia and the oxides of one or two, possibly, of the very rare metals which are allied, not with the thorium group, but with the cerium and didymium group, and those are not desirable to use in Nernst lamps or Welsbach lamps. Both of these lamps use principally the oxides of the other groups, which although they give a very brilliant radiation do not show any marked selective power as compared with the oxide of erbium; as to the selective radiation said to exist in the yellow from carbon, the fact that the yellow light appears first is, I think, due to the fact that the

eye is more sensitive to yellow light. When you raise a body to incandescence, the first light you see is absolutely without definite color. The light is so dim that there is no action upon the color detecting apparatus of the eye; so that within the range of practical illuminants I think we are going to find that the difference in radiation as regards selective action is so slight that although it may be useful in a minor way we cannot look to it for any broad method of improving our illuminants.

PRESIDENT STEINMETZ:—I might say that moderate selective radiation may occur at very low temperature, as for instance in heat fluorescence, which is really nothing else but selective radiation; that is, at a moderate temperature the body sends out luminous radiation, but it loses this feature rather quickly. I call on Mr. Ryan now to close his paper.

MR. W. D'A. RYAN:—As anticipated, I observed that my statement in regard to the luminometer working within 2 or 3 per cent. was received with some surprise. My statement is based on the results of several thousand observations. Five observers worked simultaneously, making the readings, first approaching the lamp, then receding, in order to counteract any effect due to fatigue and, while the observations of an individual would sometimes exceed the limit stated, the average of 100 observations or more on a lamp did not in any of the several tests that were taken vary more than 3 per cent. from the mean. In order to work as close as this it is necessary to test with the arc in different positions with respect to the carbon tips; that is to say, a set of observations should be made with the arc on the same side of the carbon as the observers, in order to obtain a maximum reading. A similar set of observations should be made with the arc on the opposite side from the observer, thus obtaining a minimum; the mean of the two observations will give the lighting distance of the lamp for the selected intensity. To handle the test properly special provision for rotating the lamp so as to place the arc in the desired direction was necessary, and the practical results and accuracy obtained are far in advance of photometric observations.

MR. JOHN W. HOWELL:—I would like to say just a word or two more about the selective radiation and the radiating character of different substances. The energy necessary to be supplied in order to produce light will vary as the character of the surface varies, so that there is a very material difference in the radiating character of black carbon and gray carbon, although their stability at the same temperature is practically the same. The advantage of the one lies entirely in its radiating character. The projected surface per candle of the black carbon at say 3 watts per candle is about one and three-quarter thousandths of a square inch per candle, while at the same efficiency the projected surface of the gray carbon is two and one-quarter thousandths of an inch per candle. In the Nernst lamp the projected surface per candle at the same efficiency is only about one and three-tenths

thousandths of an inch. It is only about 60 per cent. of the surface of the gray filament at the same watts per candle, which shows that its radiating character as an incandescent source of light is very much inferior to the carbon and that its efficiency is due to its very high temperature and to its very high temperature only—I believe not at all to any such characteristic as is supposed to exist in the Welsbach mantle of giving a larger amount of light at a given temperature or a disproportionate amount of light.

PRESIDENT STEINMETZ:—I raised a short time ago the question whether some of the gentlemen could give us information on other methods of illumination proposed recently, as for instance the Bremer arc lamp, the carbide incandescent lamps and some other incandescent lamps. Perhaps Mr. Howell can give us some data in regard to those illuminants, at present very interesting.

MR. HOWELL:—The only one that has come under my personal observation has been the titanium carbide lamp and those lamps which I saw were so poorly made that I was unable to determine the value of the titanium carbide filament. The exhaustion of the lamp was so poor that no matter what the filament might have been, the performance of the lamp could not be good. I expect to get in the course of a few days some more of these filaments and I hope to know more about them in a short time. (Mr. Howell reported later that they were worthless.)

MR. W. J. HAMMER:—The President mentioned the subject of the osmium lamp. I might mention in addition to the few remarks that I have made on this subject in my paper of Feb. 28, 1901, that I had hoped to present something to-night on that subject. For reasons that I cannot state here I was short-circuited in the matter. I think possibly a little later on I may be able to present the matter to the INSTITUTE.

PRESIDENT STEINMETZ:—Gentlemen, if there is no further discussion, we are through with to-day's program and a motion to adjourn will be in order.

On motion the meeting adjourned.

[COMMUNICATED AFTER ADJOURNMENT, COMMENTING UPON CLAYTON H. SHARP'S PAPER, BY T. J. JOHNSTON.]

No flame dependent upon the atmosphere for its oxygen can ever make a satisfactory standard of light: using the word standard in its ordinary sense to mean a source which shall under reproducible conditions emit identical lights per unit of area.

With such a flame there are at least four sources of error, as follows:

A. Variation of temperature of the illuminant;
B. Variation of composition of the illuminant;
C. Variation of temperature of the oxygen supply;
D. Variation of composition of the atmosphere.

Some years ago I made many photometric observations of naked flames and of flames of the argand type, having an ordinary cylindrical chimney, using an amyl-acetate standard; these were all of commercial illuminating gas. The amyl-acetate lamp was not calibrated, being furnished by the maker with the photometer. For the purposes of this communication these facts are unimportant.

I found evidence of perceptible variation in candle power within ordinary ranges of temperature. I have not at hand the particulars of the tests, but speaking from memory, the variation was about 4/10 of a candle power in 16 for a difference of 40° in temperature of the illuminant and its atmospheric supply. When I first suspected this variation I made the following test:

A tank was filled with compressed gas and exposed to outdoor temperatures until the thermometer attached to it registered approximately 30°F. The tank was exposed for several hours and when gas was released from it on the bulb of a sensitive thermometer, which had been exposed for the same length of time, it caused no variation of the mercury. The candle power of the gas was taken under these conditions at 15.6 $\pm$; the air supply was at external temperatures, or about 30° F. This test was made with as much rapidity as possible. The reservoir was then sealed off and allowed to stand until it had attained the temperature of the testing room, 70° F., and for several hours afterward. Candle power was then taken; with external atmospheric supply at 30° F. the candle power was 15.9 $\pm$; with air-supply from the testing room the candle power was 16.1 $\pm$. These tests were repeated a number of times with substantially similar results.

I did not at that time have facilities for making careful analysis of the illuminant used or of the atmosphere, and it is doubtful whether I had the technical skill to analyze gases with the required accuracy. I did, however, purposely adulterate the illuminant with known percentages of carbonic acid gas and sulphurous acid gas and this showed, as has been pointed out by gas chemists and engineers many times, that minute quantities of these produced disproportionate variations in candle power. The average of a number of tests showed that 1 per cent. of carbonic acid gas produced 10 to 12 per cent. reduction when mixed with the illuminant; the same proportion of sulphurous acid gas produced from 5 to 7 per cent. reduction. When mixed with the atmosphere supplied to the illuminant the reduction of candle power was in almost exact proportion to the adulteration.

All of the above results were, I think, subject to considerable errors, and the only safe general deduction from them is that a gas flame could not be taken as a standard when supplied with oxygen from the atmosphere. In view of this, Dr. Sharp's paper seems to present an alternative in the use of a gas illuminant of known composition supplied with a combining gas also of known composition, and which may be burned under known and definitely reproducible conditions.

Assuming that calcium carbide and water may be produced chemically pure, or at least sufficiently so for commercial results, and that oxygen may with reasonable certainty be so produced, it seems that we ought to be able to produce a light which would be strictly a standard, always provided that means are employed to keep the temperature within a limited range, though many difficulties still remain to be overcome.

DISCUSSION AT CHICAGO, JAN. 3, 1902.

THE CHAIRMAN (MR. R. H. PIERCE):—Dr. Bell's paper ends with the words, "to be continued," and I imagine, from the conclusion, that he proposes to take up various new things in electric lighting, and among them the Nernst lamp to which he refers. In what he has said he has shown enough of the general principles of illumination to enable us to anticipate the conclusions which he will draw. This is a subject I have often discussed and often heard discussed among people who have had to solve problems of illumination in a practical way. I have never seen it formally presented in this same manner before.

MR. VAN RENSSELAER LANSINGH:—Dr. Bell mentions the equation $N = cP/5\pi$. It seems to me that gives a very low figure. If we use a 16 c.p. light we have a radius of practically 1. I suppose the unit is the inch. A 2-inch diameter sphere enclosing a 16 c.p. light would be, I think, altogether too brilliant. If we use a dense diffusing globe, and cut down the light to one-half what an ordinary clear globe gives, I think even then we have too large a unit of light for good diffusion. These lights in the ceiling are using about 1 candle power per 6 square inches of surface.

THE CHAIRMAN:—On the preceding page he fixes the minimum area for a given candle power at 5 c.p. per square inch. Then on the next page he says this should be at least that radius. I presume you would agree with him that it ought to be at least that.

MR. LANSINGH:—Yes, and a great deal larger, because that is even less than the ordinary bare bulb. These lights here are almost too brilliant. I certainly would not recommend anything more brilliant than these. That is, anything that comes directly in the field of vision.

THE CHAIRMAN:—Is that not consistent with what he said on the other page?

MR. LANSINGH:—It is consistent with what he says, but I do not agree with him.

THE CHAIRMAN:—I see Mr. Lansingh is too modest to draw the conclusion which seems to be apparent from Dr. Bell's paper, but it is evident that any kind of electric light we now have has too great intensity to be used in the line of vision. The clear, open globe arc lamp has already become practically obsolete. It is a thing of the past, and I do not think it is at all radical to say that the time is near at hand when we will see no more clear

glass open incandescent lamps inside than we see clear globe, open arc lamps outside, except where they are used simply to produce a dazzling effect on the eye. They will use them, probably on State street along the edge of the show windows and in electric signs, but for the purpose of illumination there is no reason and has been no reason for a good many years, why any one should use a light of such intensity as this in the line of sight. I am glad to see this paper for the reason that I have been preaching this same doctrine myself and applying it, that is, where I have my own way, and I think there has been a great tendency in the last year to discriminate, not only between the brightness of illumination, but also between the illumination and the actual effect which is produced. I forget Dr. Bell's happy expression for the term, but we all understand what it is. When we look at one of these lights our eyes work like a shutter and put on the 64 stop, and we cut out a corresponding part of this light and use the rest to see something with. We are unwilling to go to work and cut out 10 and 20% by diffusing it, and we allow our eye to cut out 75% of it. The eye adapts itself to the light. Illumination is "all in your eye." I have put in illumination on the basis of 3,600 square feet per 16 c.p., and I have put it in on the basis of 9 square feet per 16 c.p. They were both satisfactory.

Dr. Bell's paper is really an introduction to this whole subject. This matter is also taken up more specifically by the other papers, and will be taken up extensively in discussion at New York, I presume.

The next paper, "A Note on an Acetylene-in-Oxygen Flame," by Clayton H. Sharp, describes another method of obtaining an absolute standard for measuring light.

The paper, "The Present Status of the Question of a Standard of Light," by Clayton H. Sharp, seems to conclude at the end of the paper that the incandescent lamp is the best thing with which to measure the candle power of incandescent lamps. I think all of us who have done any amount of photometric work, especially on a commercial basis, will agree with that conclusion. A few years ago we got standards from every lamp manufacturer in the United States, and it was quite interesting to make comparisons.

Mr. W. D'A. Ryan has summed up the whole of his paper in about half a page. His first conclusion is a comparison between the open and closed arcs. The open arc is practically obsolete; there will be no discussion on this point. I tried about a year ago to get a dollar apiece for 1,700 open arcs which were as good as new, and I could not get it. The open arc has been weighed in the balance.

Referring to his fourth conclusion, I would like to say that the term "effect of good lighting" is ambiguous. To some persons good lighting is something that produces a dazzling effect on the eye of the stranger when he comes to town. You can see

this effect along State street, where in some of the windows the lights are in sight and very brilliant, while in others the lights are out of sight, producing a much softer effect.

PROF. P. B. WOODWORTH:—The question of illumination is, without any doubt, one of the most important topics we have at the present time. We in America have deservedly been the laughing stock of the people in Europe on the way we use our lights. I once had the pleasure of calling on a European scholar in his study, and found he had his table illuminated with two candles, one at each side. I asked him how it happened that he was getting along with such a small amount of light. He replied that I was an American and lived where people ruined their eyes by the use of too-brilliant lights; that he had had no trouble with his eyes. He also said he could generally tell Americans from other people as they usually wore glasses

Referring to what Mr. Pierce said about illuminating windows for spectacular effect, go down State street and notice some of the windows that are lighted with incandescent lamps. In some of the windows the clear incandescent lamps stand right out, and then notice windows where the lamps themselves are not seen at all, but the goods in the windows are displayed. In one case you get an effect of light, and you might say "here is a man who is doing a lot of advertising by incandescent lamps." It is almost impossible to see anything in the windows on account of the brilliancy of the lights. In the next case, where the lamps are out of view, you are impressed with the beautiful effect of the light display in the window.

PROF. MORGAN BROOKS:—There is just one point that I might bring out, the advantage of general illumination of offices. I think you have all noticed the custom of bookkeepers who work at night, to have but a single light suspended over the desk and no other light in the office. It is a mistake not to have some general illumination in the office, so as to rest the eyes when suddenly lifted from the work. When the line of vision is thrown from a bright light into almost darkness, the eye has to accustom itself to this change, which requires effort. There should be a smaller amount of direct light and more diffused light; in other words, a uniform light. Instead of using an opaque reflector, it is much better to use a porcelain shade, so as to give general illumination. A small piece of white paper on a black board is more trying to the eye than if the board were white. The eye sees fine lines and recognizes them clearly enough, and that does not cause contraction of the pupil. Too much contrast outside of the actual field of view is objectionable, as it tries the retina more than is necessary.

THE CHAIRMAN:—That calls attention to one point which has been overlooked in this paper—that is, that the best illumination is that which is the most uniform. The first thing in laying out a practical job of lighting is to make the standard as nearly as possible uniform, because the eye will accustom itself to the

standard. The eye will adapt itself to a bright or a dark day. Uniformity is what we want.

MR. LANSINGH:—I do not think absolute uniformity is to be desired. It would not allow us to judge of shadows. We judge of the distance of objects and the shape by means of shadows cast. Take, for instance, a bright day, when there is a very hazy cloud in the sky, giving a perfectly diffused light. The sun, we will say, is not visible, but yet it is very trying on the eyes, and it is very hard to distinguish objects, not only as to their distance, but also their shape. We get the same effect on a foggy day. If we had perfectly diffused light and perfectly uniform light, I do not think it would be altogether advantageous.

THE CHAIRMAN:—Your clear blue sky is perfectly uniform light. The difference is in diffusion, not in uniformity.

MR. LANSINGH:—We do not get perfect uniformity of illumination on such a day on account of shadows cast by different things. The most perfectly diffused light is on such a day as I spoke of, when the light is most uniformly distributed. You can see the sunlight is similar to open arcs in some respects, but when you put an open arc in an opal globe, and get perfectly diffused light, you get more the light that you get on a hazy day.

THE CHAIRMAN:—As a matter of fact, I am inclined to think that the greatest uniformity we can produce artificially does not approach what we get with the kind of light we get in the day time.

MR. LANSINGH:—I agree with you. It is more a theoretical point, I presume.

THE CHAIRMAN:—Mr. Lansingh, I suppose of all the gentlemen here this evening, you are perhaps the best qualified to speak on one subject referred to by Dr. Bell—that is, the lowering of the intensity of the source of illumination. I think we would be interested to know what standard, if any, he has used for that purpose.

MR. LANSINGH:—I do not know of any standard being used in general. For my own practice I have adopted five to six square inches per candle power for general illumination. That applies usually to low rooms and it cannot be taken as a standard in every case, by any means. For a room like the present one, I adopt such a standard. A 16 c.p. lamp is supposed to give 16 c. p. in its horizontal intensity. I wish to call attention to one more point with reference to the shade. It is swinging slightly now, and that is the general condition in which such shades are used, supported by a cord. If you should hold a piece of white paper underneath it, you would find that there are parallel white lines and streaks passing over that paper, and those are extremely hard on the eye. That has the same effect as unsteadiness. A shade only intensifies the lines which are naturally inherent in the bare incandescent lamp. For that reason all forms of such shades are very hard on the eye.

THE CHAIRMAN:—I would like to ask if anyone has had any experience in measuring candle power of Nernst lamps.

MR. W. B. HALE:—I measured one of the Nernst lamps, the German make, a few days ago, and obtained a maximum of 68 c.p. horizontal, with 100 watts. That was an efficiency very much higher than ordinary incandescent lamps—about .9 of an ampere to 110 volts. In the Nernst lamp the heating coil obstructs a large part of the light.

PROF. WOODWORTH:—That is in the German lamp. The American lamp does not do that. It has a heater above the glower which is more efficient than the German spiral, and at the same time assists in the reflection of the light.

[Adjourned,]

A paper presented at the 159th Meeting of the American Institute of Electrical Engineers at New York, Jan. 3, 1902.

EDISON'S TUNGSTATE OF CALCIUM LAMP.

BY WM. J. HAMMER.

Through the courtesy of Mr. Edison, I am enabled to present to the INSTITUTE this evening several samples of what has been termed "Edison's X-ray lamp," of which brief descriptions have been given in the press on several occasions. But this occasion is, I believe, the first time that the lamp has been publicly exhibited. It is well-known that in connection with Mr. Edison's experiments with Roentgen rays, and in the construction of his fluoroscope, he experimented with thousands of chemical substances, and the substance which he found most suitable for use on the fluorescent screen was tungstate of calcium, which, together with barium platinum cyanide, constitute the substances most extensively employed in fluorescent screens.

Mr. Edison has also made a large number of experiments in which he has fused certain fluorescent substances on the internal walls of X-ray tubes, which substances upon being excited by X-rays have caused the tube or globe to glow with great brilliancy. I have a number of tubes or lamps of this type which I had hoped to have the pleasure of showing you this evening.

These lamps are coated internally with tungstate of calcium; the crystals of which have been fused by the X-rays, the tube being slowly rotated while the substance is being acted upon. The apparatus which is before you is the same apparatus which I used last evening in operating these tubes most successfully at my house; and Mr. Edison also showed me these tubes operating at his laboratory most successfully the day before yesterday.

I regret to state that while making some experiments with my large coil early this evening, the secondary winding was broken down, and I will not be able to show you the lamps burning under the best conditions, at which time they present a very

brilliant and beautiful light, although it is not at present possible to operate them continuously for any great length of time.

Through the courtesy of Mr. Hewitt, who has kindly lent me his small coil, I will be enabled to operate one of the tubes which I have, and which will serve to indicate to some extent the results of Mr. Edison's experiments in this direction. The other three tubes which I have are of too high a vacuum to operate successfully on this small coil.

Nernst Lamp.

I had hoped to have the pleasure of showing you this evening one or more samples of the osmium lamp, and to tell you some things of interest connected therewith; but it seems that the time is hardly ripe for the presentation of this matter before the Institute, though I hope to do so in the near future.

I am enabled, however, to present for your consideration tonight various types of American, English, German and Hungarian Nernst lamps, of both self-lighting and torch-lighting types. Some of the foreign types of lamps I had the pleasure of describing in detail in my paper at the 151st general meeting of the Institute on Feb. 18, 1901; and the Westinghouse type of Nernst lamp has been very ably presented to your notice by Mr. Alexander J. Wurts at the summer meeting of the Institute at the Pan-American Exposition at Buffalo.

Therefore, in view of the extent of our program this evening, I will not go into details regarding these lamps, which may be examined at the close of the meeting, but would call your attention in passing to the German Nernst lamps which are shown burning here this evening, and which are the latest types manufactured by the Allgemeine Electricitäts Gesellschaft of Berlin, and which have very recently arrived on this side of the water. The large lamp containing the pendant conical heating coil is of a new type, which is here publicly presented for the first time. I would refer those particularly interested in this subject to papers already referred to, which have been presented to the Institute.

Radium.

Since the discovery a few years ago by M. Henri Becquerel of the remarkable uranium radiations, which have since been known by his name, such an amount of attention has been given by physicists to the study of radiant matter, and to speculative theories as to the constitution of matter, that it will probably be some time before our views can settle down and adjust them-

selves to the new phenomena which have been presented and are daily being brought to our notice.

Becquerel demonstrated that compounds of uranium, and especially the metal itself, prepared in the electric furnace, possessed very great radio-activity. Thorium compounds, especially thorium oxide, are next in activity, though far weaker.

Mme. Sklodowska Curie and M. Pierre Curie noted that other elements were inferior to these, and that the compounds were inferior to the metals themselves. Bohemian pitch-blende and two other compounds of uranium suggested to them by their greater radio-activity to that of pure uranium, that some new substance existed more active than uranium, and after most exhausting and painstaking investigations, they discovered a metal identical with bismuth in its chemical characteristics, and far more radio-active, which they named "polonium" after Poland, Mme. Curie's fatherland. A further search resulted in the discovery of another new metal very similar to barium in its chemical properties, which they called "radium," which was even far more radio-active. This was followed by the discovery by M. A. Debierne of a third element, which he has named "actinium," which has chemical characteristics similar to titanium. It has as yet not been fully demonstrated that these three are actually new elements, as none has as yet been secured in a pure state.

It is not my purpose to-night to go fully into the investigations which have been made in these remarkable substances, with which many of you are doubtless familiar; but in view of the interest which radium has excited in the scientific world, and as there are probably few in this audience to-night who have had an opportunity of seeing this remarkable, and up to the present time, exceedingly rare substance, I take pleasure in presenting a small quantity for your consideration, which I have secured through the courtesy of Prof. Dayton C. Miller, who imported the same from Paris. The tiny sealed glass tube, which I hold in my hand, contains about two grammes of radium, which cost in Paris about ten dollars.

I have prepared a few notes regarding certain properties of radium, which I will read, and which I trust will prove of interest,[1] after which, if the lights are put out, I will pass around

[1] Prepared from compilations of E. E. Fournier D'Alva in *London Electrician*, *Science Abstracts* and other sources, these being abstracts of *Proceedings of Royal Soc.—Phil. Soc.—Phys. Zeitschrift—Ann. der Physik—Deutsche Phys. Ges. Verh.—Chem. News—Comptes Rendus—Soc. Francaise Phys. Bull.—Jour. de Physique*, etc.; see also, Prince Kropotiscin on "Recent Science" in *The Nineteenth Century*.

the room, and you can observe not only the illumination produced by the radium itself, but also the radio-activity of the cotton, which I will wrap around the tube.

An extensive dealer in chemicals informed me recently that the treatment of 100,000 tons of uranium residues would probably not result in the production of a kilo of radium. The present market price in this country is $4.50 per gramme, or approximately $2,000 a pound.

M. and Mme. Curie and Mr. H. Geitel have succeeded in further purifying radium, and I understand that a preparation will shortly be on the market here at the cost of $35 per gramme. The chloride and bromide of radium are the most brightly luminous compounds, but all the salts are more or less radio-active.

The radium preparation which I am able to show you to-night differs from such substances as sulphate of lime and various compounds of barium, calcium, strontium uranium, etc., which possess the property of glowing in the dark when exposed for some time to light, or are rendered active by electrical or heat vibrations, in that radium requires no such exposure to become incandescent, but will glow for months and even years, and also has the property of causing other substances near it to become radio-active, and to retain this activity in many cases for a long period. Radium has been called a constant source of " X " or Roentgen rays and cathode rays.

H. Becquerel estimates that the energy expended by radium is a few C. G. S. units per second, and a few ten millionths of a volt, and that at this rate the loss of matter would be about one milligramme in a thousand years. He also finds that the radio-activity of radium is 900 times that of metallic uranium, while that of polonium is only 400 times.

He also calls attention to the facts demonstrated by M. and Mme. Curie and himself, that radium radiations carry negative charges like cathode rays, and like cathode rays also can discharge electrified bodies at a distance as well as render the air gap between the plates of a condenser, conducting; and the current passing, susceptible of measurement by an electrometer. Also that many bodies when exposed to radium influences acquire temporarily the power of rendering the air conducting, and of discharging electrified bodies, all of which afford proofs of the contention that there is in reality a continuous emission of energy by transport of matter from radio-active bodies; and

H. Becquerel estimates the speed with which these particles are radiated at half to two-thirds the speed of light.

These investigations have also shown that radium radiations are of three kinds, a portion deviable by a magnetic field, a portion non-deviable and readily absorbed, and a third weaker portion of diffused, non-deviable rays attributable partly to secondary rays.

M. and Mme. Curie state that the deviable rays have the greater penetrative effect, but constitute but a small portion, and that the non-deviable rays, which constitute the major portion, do not travel further in the air than 7 cm. from the source. According to M. Becquerel, there seems to be no difference in the deviable qualities of radium rays in the air or in a vacuum. M. and Mme. Curie show that polonium only emits non-deviable rays, and that these only travel 4 cm. from the source in air.

Giesel's polonium, on the contrary, emits both deviable and non-deviable rays; and J. Elster states that magnetic deviation of polonium rays is produced in a vacuum, and seems to exceed deviation of radium rays under same conditions.

S. Meyer and E. R. Von Schweidler, in studying the absorption of radium rays call attention by plotted curves to the fact that the first few hundredths of a millimetre are most effective in the absorption, and that it may be concluded that with radium rays, as in the case of Roentgen, uranium and thorium rays, the radiations consist of a large number of rays of different nature.

According to M. and Mme. Curie, radium rays act in many ways like light. They reduce silver salts, peroxide of iron and bichromate of potash in presence of organic substances; but they also color glass, porcelain and white paper, and they transform greenish yellow platino-cyanide of barium into a brown variety.

Giesel had prepared platino-cyanide of barium with a trace of radium. This spontaneously became brown, and it then polarized light like tourmaline. He also found that this colored rock salt just as cathode rays do, or the vapors of alkaline metals, and furthermore showed that radium salts, brought near the temples or to the closed eyes, produced a sensation of light.

M. Becquerel, referring to the chemical action of radium rays, says that radium and uranium rays act upon silver gelatino-bromide, but produce no effect upon Daguerre plates, or upon photographic papers, and says that colorations of glass, porcelain, paper and certain crystals, as well as the painful physiological effects, also belong to this class of phenomena. He also

calls attention to the transformation of white into red phosphorus in 24 hours, the reduction of mercuric chloride in the presence of oxalic acid with the precipitation of calomel, and finally the destruction of the germinating power of seeds after long exposure.

Becquerel also shows that radium rays possess the same power as the electric spark, or the prolonged action of violet or ultra-violet rays, of restoring the phosphorescent properties under exposure to heat of a body deprived of them by over-heating.

O. Behrendsen found that by cooling radium in liquid air its radio-activity was reduced more than one-half. On heating again to a normal temperature, a slight increase of radio-activity was discovered, thus agreeing with the behavior of phosphorescent bodies described by Lumiere.

Curie and Debierne state that while all bodies become radio-active when placed in a closed vessel with solid salt of radio-active barium, this effect may be increased 40 times and made more regular by using the aqueous solution instead of the solid salt.

M. A. de Hemptemne, who discovered that gas which becomes luminous at a certain pressure under the influence of electrical vibrations becomes luminous at a higher pressure when exposed at the same time to " X " rays, also found that air which became luminous only at an exhaustion as low as 33 mm, became luminous at a pressure of 44 mm, brought into proximity with a radio-active substance, and at the same time the color of the light changed from reddish violet to yellowish green.

Dr. C. Runge, the great German specialist, found that radium gave three distinct lines belonging to no other element. Demarcay had previously given these lines, together with some twelve others which he claimed to belong to raduim, but thus far had not been proved to belong to radium.

Radium rays, like Roentgen or " X " rays, produce serious physiological effects. This was first demonstrated by Messrs. Walkoff and Giesel, the latter having kept on his hands for two hours a celluloid capsule containing radiferous barium bromide. The rays acting through the celluloid caused a slight redness of the skin, and two or three weeks later inflammation set in, and the skin finally sloughed off.

M. Curie repeated Giesel's experiment upon himself, using radiferous barium chloride, acting through a thin sheath of gutta percha, upon his hand. The activity of the substance was

comparatively feeble, being about 5,000 times that of metallic uranium. The rays left a red spot on the hand six centimetres square, which appeared like a burn, but gave no pain. In a few days the redness increased, and on the twentieth day crusts formed, ending with a sore which needed dressing. On the forty-second day the epidermis commenced to form on the edge, and fifty-two days after the action one square centimetre remained sore and of a greyish color.

M. Becquerel, on carrying a small sealed tube containing a few decigrammes of very active radiferous barium chloride, the activity of which is 800,000 times that of uranium, underwent an experience of the same kind. The matter enclosed in the glass tube occupied a cylindrical volume of from 10 to 15 millimetres by 3 millimetres in diameter; the tube wrapped in paper, was kept in a small paste-board box. On April 3 and 4, this box was placed several times in a corner of a vest pocket for a period, the total duration of which amounted to six hours. On April 13 it was perceived that the radiation through the tube, the box and the clothes had produced a red spot on the skin, which became deeper as the time passed, marking in red the oblong form of the tube, and assuming an oval form 6 centimetres long by 4 centimetres wide. On April 24 the skin fell off; then the part most affected sank in, beginning to suppurate; oleo-calcareous dressings were applied to the sore for a month, the diseased tissues were removed, and on May 22, that is to say, forty-nine days after the action of the rays, the ulcer closed, leaving a scar which marked the place of the tube.

"While care was being given to this burn," he says, "there appeared about May 15 a second oblong red spot opposite the other corner of the vest pocket in which the active matter had been placed. The exposure had been of short duration, an hour at most. Erythema now appeared, thirty-four days at least after the exciting action; inflammation developed, presenting the appearance of a superficial burn; on May 26 the skin began to fall off; on receiving the same care as the first, this burn appeared to be more rapidly cured.

"In the interval of these observations, on April 10, 11 and 12, the same tube of active matter, enclosed in a lead tube, whose walls were about 5 millimetres thick, was kept for forty-hours in another vest pocket, but has so far been attended with no physiological effect."

"It may be added that Mme. Curie, by carrying in a small

sealed tube, a few centigrammes of the same very active matter which had caused the effects described above, had similar burns, although the small tube was enclosed in a thin metallic box. In particular, an exposure of less than half an hour produced at the end of fifteen days a red spot, resulting in a blister similar to a superficial scald. Fifteen days were required for the cure. These facts prove that the duration of the effects varies with the intensity of the active rays, and with the duration of the exciting action."

"Our hands have been also affected. There has been a general tendency to desquamation, the extremities of the fingers which have held the tubes or capsules containing active products become hard and very painful. In the case of one of us, the inflammation of the extremities of the fingers lasted about fifteen days, and indeed after the falling off of the skin, the painful sensations have not yet completely passed away at the end of two months."

As illustrating the action of radium rays upon bacteria, E. Aschkinass and W. Caspari speak of exposing cultures of *micrococcus prodigiosus* to a radium preparation, and state that the rays killed the germs very effectively in about three hours

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

NEW YORK, January 13, 1902.

The annual dinner of the INSTITUTE was held this evening at the Waldorf-Astoria, the guest of honor being Mr. Guglielmo Marconi, the distinguished Italian space telegraphy expert. The brilliant assemblage of guests, numbering nearly 300 members and ladies, among them some of the foremost men in the various professions, made the occasion one of the most successful ever arranged by the INSTITUTE. The Astor Gallery, where the dinner was held, was decorated with novel and beautiful effects. Along one side of the room under a huge American flag, was a big table upon a dais; at the table were seated President Steinmetz, Past Presidents Elihu Thomson, Alexander Graham Bell, Francis Bacon Crocker, Frank J. Sprague and Carl Hering; Sir Percy Sanderson, C.B., the British Consul General; Cav. Branchi, the Italian Consul General; Dr. M. I. Pupin, William Stanley, Charles W. Price, Arthur Williams and the toast-master, Past President T. Commerford Martin. The menus were made interesting by clever sketches of Marconi staffs on the coast lighthouses, signalling "ss" in three dots, all the way across the ocean. By means of flexible conductors and tablets, the room was decorated with hundreds of electric lamps, while very small green lamps were inserted in great coils of the conductors upon the tables. On large tablets at either end of the dining hall were the names "Poldhu" and "St. Johns," in letters formed of electric lamps, and opposite the speakers' table was another tablet bearing the name "Marconi." In strands of the conductor which was strung so as to connect the three signs, were inserted clusters of three lamps at frequent intervals, designed to represent the three dots or "s" flashed by Mr. Marconi's assistant across the Atlantic from the coast of Cornwall to Newfoundland. These were flashed now and then or allowed to remain lighted, forming an appropriate and novel feature of the dinner festivities. In keeping also with the spirit of the evening was the procession of waiters carrying assorted ices, which were formed in semblance of electric lamps and automobiles grouped at the bases of telegraph poles. From these poles

dangled broken wires,and between tho poles were carried ships and other symbolic designs. All of these features were loudly applauded by the guests at the tables and in the galleries.

After dinner was over, President Steinmetz greeted the guests and cordially welcomed Mr. Marconi.

PRESIDENT STEINMETZ:—Ladies and Gentlemen: It is extremely gratifying to me that I am enabled to greet you at this, the annual dinner of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS. I believe I voice the sentiments of all when I say that we are extremely sorry not to have with us the grand master of our industry, Mr. Edison, who from the early days of our profession has been working with us, and is still actively engaged in pioneer work of highest importance; he who has, I may say, founded our industry and has been principally instrumental in developing it and thereby enabling us, who constitute the profession, to be what we are at present.

I am glad, however, to introduce to you to-night another genius; an engineer who has been distinguished on both sides of the Atlantic by his work; who, taking up where Mr. Edison left off in the beginning of his career, has advanced beyond what others have done. While telegraphers have sent their messages through wires over the country or through cables across the Atlantic, and telephony has made talk possible over great distances; Mr. Marconi, our distinguished and honored guest, has done more. Instead of sending messages across the seas by cables, he has succeeded in sending them across empty space through the luminiferous ether.

I am glad and very thankful that we have with us this distinguished guest from abroad. I do not need to dwell any further upon this because we will have the pleasure of listening to him after a very short while, and I understand that Mr. Marconi will give us an explanation of what he has done and of what he hopes to do in the near future.

I now will turn the chairmanship of this meeting over to Mr. Martin as toastmaster. I hardly need to introduce Mr. Martin to you, because you have known him for years and years as a toastmaster. While presidents come and go and other officers of the INSTITUTE, Mr. Martin's efficiency as a toastmaster, as we all remember from many enjoyable social gatherings, has been so prominent that nobody has ever been found who could anywhere nearly equal his mastery; and, if you do not believe this, you will see for yourselves how true it is. (Laughter and applause.)

TOASTMASTER MARTIN:—On such an eventful, memorable and delightful evening as this in the history of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, there is fortunately very little left for the toastmaster to do. In company with the rest of the committee, he has simply been loafing and idling during the last forty-eight hours. (Laughter.) We were not quite sure when Mr. Marconi would get through in Canada, or whether he was

going to Vancouver, or was about to try experiments on the Pacific Ocean. When we succeeded at last in locating him, we had barely forty-eight hours left us in which to organize this banquet. On behalf of the committee, and particularly of Mr. Calvin W. Rice, our Chairman, I beg you to accept our most profound and humble apologies. We have done our best. (Applause.)

The first duty which devolves upon me this evening is to read to you various communications which have been received by our committee. One, which is in autograph, and a fac simile copy of which I think everyone here would like to have, is as follows:

I am sorry that I am prevented from attending your annual dinner tonight, especially as I should like to pay my respects to Marconi, the young man who had the monumental audacity to attempt and succeed in, jumping an electrical wave clear across the Atlantic Ocean.

Yours,

EDISON.

It was absolutely impossible for Mr. Edison to be with us tonight, but he said he would be thoroughly well represented when he sent his better half, (Applause). I may add that within the last ten days I had the pleasure of speaking to Mr. Edison himself with regard to Mr. Marconi, and he said that he had thought that sometime or other there might be signals flashed either way across the Atlantic without wires, but that he did not know when, and being pre-occupied, he did not think he would have time to do it himself, and he said to me: "Martin, I'm glad he did it. That fellow's work puts him in my class. He is a worker. It is a good thing we got him young."

Gen. Miles, the Commander-in-Chief of the United States Army, was to have been with us this evening, indeed, he accepted our invitation; but later he found it impossible for him to leave Washington, and he sent this evening a personal message to Mr. Marconi, and also to the INSTITUTE through Col. Samuel Reber, one of our officers, in which he desired him to express his great regret at his inability to be present, and his pleasure in knowing that we were extending this honor to Mr. Marconi as our guest.

I now have the pleasure of reading the following which is headed "City of New York," and is from the office of our wireless Mayor. (Laughter and prolonged applause).

I am sorry that it is not in my power to attend the dinner of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS to be given this evening, at which Mr. Marconi is to be the guest of honor. The results already obtained by Mr. Marconi mark him as a man who has been a benefactor of the race, and his latest achievements seem to give promise of still greater services to mankind. I wish it were possible for me to be present to say to him in person, on behalf of the City of New York, how highly his scientific labors are appreciated. Asking you to convey to him my regards and best wishes, I am, respectfully,

SETH LOW,
Mayor.

I hold before you, fellow-members of the INSTITUTE, the record of the dinner given to Cyrus W. Field in this city thirty-five years ago, when, after labors that were superhuman and devotion and courage that were almost immortal, the Atlantic cable had at last been finally and successfully laid. Mayor Low's father presided at that dinner, and this is Prof. Morse's own copy of the record. I thought it would be interesting to bring it out of my little collection this evening and put it on the table.

The following letter has been received from the President of Columbia University:

> I regret deeply that a previous engagement for the evening of Monday will debar me of the pleasure of accepting the invitation that I have received from Prof. Sever to be present at the dinner tendered by the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS to Signor Marconi. I greatly regret my enforced absence for I should enjoy being able to join in your tribute of respect to the distinguished inventor, and in felicitating him upon having placed his name on the roll of the great discoverers and the great benefactors of the human race, for there appears to be every reason to believe that the most important practical results will follow in due time from Signor Marconi's successful experiments. Pray tender to your distinguished guest an expression of my sincerest congratulations and high regard, and believe me,
>
> Very truly yours,
>
> NICHOLAS MURRAY BUTLER

From Capt. Chadwick of the United States Navy, whose name is remembered whenever we celebrate American victory and American valor, the following was received:

> I greatly regret my inability to attend the dinner in honor of Mr. Marconi. It would afford me great pleasure to be present to give in evidence my esteem and regard for him. I know him well enough to know that his genius is equalled by a modesty and reticence of statement, for which I have an equal admiration with the best. When he told me last Spring of his hopes, I knew he would do more than he mentioned. The result has more than justified expectancy.
>
> F. E. CHADWICK.

I will also read the following letter to Mr. Rice as Chairman of the committee:

> Replying to your kind invitation which was delivered during my absence from the city, I beg you to transmit to the INSTITUTE my thanks for the honor proffered. I feel that I could not rise to the occasion, and regret not being able to contribute to the pleasure of the evening; but I wish to join the members in heartily congratulating Mr. Marconi on his brilliant results. He is a splendid worker, full of rare and subtle energies. May he prove to be one of those whose powers increase and whose mind feelers reach out further with advancing years for the good of the world and the honor of his country.
>
> Yours very truly,
>
> NIKOLA TESLA.

Permit me to say, gentlemen, even if it be a personal allusion, that from my beloved friend Tesla these ten years gone, I learned to believe that it would be possible to do what Mr. Marconi has now done.

As you are doubtless aware, our esteemed friend, Mr. George G. Ward, Vice-President of the Commercial Cable Company, is the representative in this country of the Institution of Electrical Engineers of Great Britain, of which our guest this evening, Mr. Marconi, is a member. I have received the accompanying letter from Mr. Ward, from which you will gather that he still believes in the laying of submarine cables.

Your letter of January 10th, conveying the kind invitation of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS to join with them on this Monday evening, was delivered while I was away from the city, in Washington. I regret to say that I am unable to accept the invitation. I am compelled to return to Washington this afternoon to attend to matters in connection with the laying of the Commercial Pacific Cable. I congratulate the society upon its distinguished guest. I am very sorry I cannot be there to meet him.

Yours very truly,

GEORGE G. WARD.

I wish to say that Mr. Ward called me up on the telephone and asked me to take Mr. Marconi by the hand and shake it, and say that everything that would further the cause of communication between the hemispheres he was with and for.

Mr. Marconi had the distinguished honor of being born an Italian. I have had handed to me this evening by the Italian Consul in this City, a message which he has received from the Italian Ambassador to this country, which it will afford me great pleasure to read to you.

Absent because of previous engagements of importance from the dinner which the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS gives in honor of Signor Marconi, I beg you to offer my assurance that I am present in spirit and rejoice in the sympathy shown for our illustrious countryman who adds his own to the other great Italian names of Volta, Galvani, Pacinotti and Ferraris in the history of electrical science. The new invention of Signor Marconi whose development will unite more and more firmly the new and old world in all their relations, is really an inestimable victory of human genius over the forces of nature; a noble conquest of civilization and mankind. I salute my glorious compatriot, and thank the worthy and high honorable Association which so fraternally welcomes and lauds him and his achievement.

THE ITALIAN AMBASSADOR TO THE UNITED STATES.

If you will look at your menus, gentlemen, on the second page you will find enumerated one or two of the European societies to which our guest of honor belongs. We have deemed it fit and appropriate that with them this evening we should exchange fraternal greetings, and one of the officers of the INSTITUTE, in conference with President Steinmetz, has prepared, with the permission of Mr. Marconi, cable messages, which, with your approval and consent, we shall take pleasure in forwarding. I have pleasure in calling upon one of our members, not less well-known in Italy than in this, his own, country, Mr. John W. Lieb, who was associated with the Edison Company in Milan for years, to read you the despatches which it is proposed to forward.

Mr. Lieb then read a series of cablegrams to be sent to the various foreign organizations with which Signor Marconi is associated, and, on motion, the Secretary of the INSTITUTE was authorized to forward the same on behalf of the Society.

THE TOASTMASTER:—A distinguished English architect, when asked what his monument might be, and, in fact, it was afterwards inscribed as his epitaph in St. Paul's Cathedral, London, said, "Look around you." In introducing the guest of honor this evening all that I will say, gentlemen, is, look at these illuminations around you and three cheers for Signor Gugliemo Marconi. (Loud applause.)

SIGNOR MARCONI:—Mr. President, Ladies and Gentlemen: I can hardly find words to express my gratitude and thanks for the reception I have had here to-night. I thank you very much for the appreciation of the work which I have been fortunate enough to carry out. I feel myself highly honored to be entertained by such a great body as the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS. I think it is well-known all over the world that Americans stand first in applied electrical engineering. I feel myself greatly honored to be among so many eminent men, whose names are household words in the whole civilized world.

With your permission I will give you a brief description of what my system has at present accomplished, especially in reference to use on ships, and what I hope it will accomplish in the future. Wireless telegraphy is now attracting very great attention all over the world, and its progress is not slow. Five years ago the system with which my name is identified was working over a distance of about two miles, but its range has been rapidly increased until a few months ago it was quite possible to communicate by means of an improved and attuned system over a distance of 200 miles. The commercial application of the system has been given serious consideration, and improvements of importance have been made.

It may interest you to know that the commercial application of the system has been tried in Great Britain, its chief base being in England. It may interest you, also, to know that there are over seventy ships carrying permanent installations for wireless telegraphy. Of these thirty-seven are in the British Navy, twelve in the Italian Navy and the remainder are on the large liners, such as the vessels of the Cunard Line, the North German Lloyd and the Beaver Line.

There are over twenty land stations equipped in Great Britain and on the Continent of Europe, which work in connection with the ships, and several on this side of the water, and a certain number of Lloyd's signal stations are now being equipped.

I regret very much that it is impossible for me in a brief address to go into the scientific details or into the historic development of my system, but I would like very much to reply in some way to the questions that are constantly asked as to the practical working of this system. I think I am right in saying that it is

the general belief that when a message has been transmitted, or, as we might say, has once been entrusted to space, anyone with an appropriate receiver will be able to take it up and thereby find out what the message is and other people's business. This, in a commercial enterprise, would be very awkward, because nobody would like to send messages, and certainly commercial messages, such as stock quotations or private messages, if they thought that other people would get hold of them. By experiments and improvements which have been made, messages can only be read when the receiver and the transmitter are attuned. This perfected system is not at present in use on the ships. It has been deemed necessary that each ship should be equipped with apparatus which will permit of its reading a message sent from any other ship, because of the possibility of aid being required in distress. Therefore, the apparatus on all ships is attuned so that one ship may call up any other ship; but it is practicable to have the apparatus so attuned that the messages transmitted can in no way be received by any other apparatus except that attuned to receive the message.

In the case of transmissions from land to land, or across land, what we call the attuned system must be used. I will refer the technical gentlemen, who are here present, for details as to my work on that subject to a paper published by the Society of Arts in May of last year. With reference to what has already been accomplished at short distances—what I call short distances is up to two hundred miles—I refer you to some remarks which I will read, made by Prof. A. Fleming, who is professor of electrical engineering in London University, and who is well acquainted with the wrokings of my system. In a paper that he read on "Electrical Oscillations and Waves" before the Society of Arts in December, 1900, he said: 'Communication was established by the Marconi system for the Admiralty between Portsmouth and Portland, two places about sixty-five miles apart, in a straight line, having hills eight hundred feet high in the line of sight. Across this line of communication, and included in it, there is another thirty-mile Marconi circuit between stations. These two lines cross each other at not a very great angle. By the employment of properly attuned receiving and transmitting circuits, it has been found possible to render these circuits quite independent of each other, so that no messages which go on between either two of the stations can interfere with messages being sent between the other two stations. What has been done here can be carried out indefinitely, and the objections as to interference of stations which uninformed persons are in the habit of raising, with regard to the system of wireless telegraphy, as a matter of fact no longer exist."

I have mentioned that I found it possible by means of the attuned system to transmit messages a distance of two hundred miles. Transmission was obtained between stations in England and Ireland, even in cases when a very small amount of energy

was used—perhaps only as much as a very small incandescent lamp. That was found sufficient to telegraph two hundred miles. But it was at once thought that by the rational application of large amounts of energy, which electrical engineering has taught us how to produce with ease and to utilize, it would be possible to transmit messages to a much greater distance than had heretofore been dreamed of, or found possible. With the intention of demonstrating that trans-Atlantic transmission was possible, two comparatively very powerful installations were set up, one in Cornwall, Eng., and the other at Cape Cod, Mass. Prof. Fleming, of the University College in London, assisted me greatly in the installation of the powerful machines required. An unfortunate accident, which was caused by a hurricane at Cape Cod, partly demolished that station and for a few months at least, caused the postponement of the tests which I intended to carry out between England and the United States.

As I did not want to wait until repairs were effected at Cape Cod, I thought it might be useful in some way to get the English station to transmit with its full power, and the messages to be received on this side by means of a temporary installation; and as I did not think it prudent to try such a distance as three thousand miles at once, I thought that this temporary installation, this first shot of getting messages across the Atlantic, should be tried on the Island of Newfoundland, at St. Johns, which is about two thousand land miles from England. Instead of poles, as are generally used for permanent work, kites and balloons were employed to elevate the aerial wires, the necessity of which I think you are pretty well acquainted with. These kites or balloons gave a great deal of trouble, as, owing to the tempestuous weather which prevailed in Newfoundland last December, it was found almost impossible to raise the kites or balloons to the required height. However, I am glad to say that at certain intervals, on the 12th and 13th of December, the kites were for a short time got into satisfactory position, and my assistants and I had the great satisfaction of receiving a number of the prearranged signals from Cornwall, at the right time and at the prearranged speed. (Applause and cheers.)

Experiments would have been continued in Newfoundland with a more permanent installation, as I at once recognized the unsatisfactory results which were obtained by an installation which depended on the wind and weather, which in those northern regions are very unreliable in winter; and this permanent installation would have been set up, had I not discovered the fact that the Anglo-American Telegraph Company has, or claims to have, a monopoly of all telegraph communication in that colony (Laughter); not only has it got the cable and ordinary communication, but it claims to have the monopoly of preventing anyone from trying experiments which are connected with telegraphy in that colony, and in a certain way claims to have a monopoly of the air and the sea. (Laughter.)

It is rather strange, I may mention, that in England the British Government has the monopoly of the telegraph, and I am glad to say that it has encouraged my experiments rather more than prevented them. Certainly, when it comes to commercial work between stations in England—not between stations in England and ships, but between stations in England—we have come to a suggested arrangement; and I do not think the British Government would have thought of interfering with experiments, the object of which was the advancement of science. In Newfoundland, although we were not interfering with the revenue, but rather increasing it, due to the cabled results of my experiments and of what was going on (Applause), I was told by the manager of the cable station at St. Johns that he was pleased that I had provided a revenue for the company, because during the three days I was there they sent fifty thousand words over the wire. Still, we had to stop, and I do not think it wise to put up a permanent installation there.

My colleagues in the electrical profession well know, and in other professions too, that it is difficult enough to push a new thing when it is practically unimpeded, and that it becomes almost an impossibility when you have got to face injunctions and threatened injunctions.

Well, under the circumstances, I thought I would cross over to a country that is not very far from Newfoundland, about ninety miles away, Nova Scotia, part of the Dominion of Canada; and I think that a permanent station will be erected there, and that the one at Cape Cod will be repaired, and I am confident—perhaps inventors sometimes, or what are called inventors, are over-confident—that it will be possible to transmit messages, and perhaps several messages across the ocean at the same time, and in a commercial and sure manner.

I wish to state here before you all that I am very greatly indebted to the governments of Newfoundland and Canada for the encouragement, sympathy and assistance they have given me in my work, and I trust that the future results will bear out our hopes and expectations.

I think it is generally admitted that modern history has proved beyond a doubt that one of the greatest factors of civilization in all the progress of the world is the facility with which people living long distances apart can readily and quickly communicate with each other. If my system can be commercially established, which has yet to be proved on long distances, between the different parts of the earth, it will not fail to bring about a further great cheapening of the methods of communication. An installation that will work across the Atlantic, however elaborate, costs only a very small fraction of what a cable costs. At present the great cost of the cables themselves and their heavy working expenses, causes the existing method to be beyond the reach of the majority of people inhabiting the various countries, but I believe that should my dream be realized and this

new method be applied, the cost of cabling to distant countries will be very greatly and substantially reduced. A cheap telegraphic service between united families, however scattered, would keep the dispersed members in close and constant touch with the old home, and would cement friendships between the people of this great nation and the other nations of the globe—forging another link in the ties which bind this country to Great Britain. (Applause).

Time has not permitted me—I have said this before—to make any reference to the history of wireless telegraphy. I wish you to know how much the success of my work has depended upon the work of my predecessors and my present assistants. I have built very greatly on the work of others; and before concluding, I would like to mention only a few of the names; I may omit some, but these occur to me at present. They are Clerk Maxwell, Lord Kelvin, Prof. Henry and Prof. Hertz. (Applause.) I do not know if you are all aware of it; I think it has been well published in the daily press, with more or less accuracy, that these messages were received on the telephone which was actuated by the impulses translated through it from a coherer which was influenced by the electric rays coming from England, and I wish to mention the name of Prof. Alexander Graham Bell in that connection. (Applause.) If it had not been for the invention of the telephone, I do not know whether at this day we would have received signals across the Atlantic. They might have been received later, with a great deal more power. An ordinary recording instrument was not sufficiently sensitive to work at that distance, but, by the aid of the telephone, it did work.

Gentlemen, I can hardly express how grateful I am for your hospitality and the kind references which have been made to my work. I hope that I can bring this work to a successful completion. As a stranger here, I thank you very much for your hospitality, and now I have the honor to drink the health of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

Mr. Marconi took a glass from the table, holding it high above his head, then lowered it to his lips, and the diners doing the same, drank the toast in silence.

THE TOASTMASTER.—When on Sunday last your committee had the honor and pleasure of meeting Signor Marconi and telling him that it was " up to him " they had a very quick appreciation of the fact that when he came before you this evening he would justify the expectation which we entertained when we desired his presence among us to-night as our guest of honor. And when, during that long and laggard leisure which was at the disposal of your committee in making the arrangements for this banquet to-night, we cast around in a desire to rally the best spirits in the INSTITUTE about us, needless to say, our first thoughts turned to New England and to Prof. Elihu Thomson. While Prof. Thomson lives in New England, in these days of

rapid transit that is no impediment to New York citizenship. We have understood that either to him, or to Mr. Lockwood, is attributable that remark of a Bostonian, living somewhere within the periphery of the Hub, that one of the best things about Boston was the 5:30 express for New York. Prof. Thomson knows that whatever train he takes for New York, he is equally welcome—with due respect to the New York *Sun*—in our midst.

Prof. Thomson and myself, and one or two others, around this board to-night, have somewhat of a reluctance in uttering the phrase "Anglo-American"; but, gentlemen, as you know, this country, in the cordiality which it extends to talent and genius of every kind, has not drawn the line at the little island that sits within the seas, but has welcomed the old and great continent of Europe. When Signor Marconi came to this country he also had a whole continent, presumably, at his disposal; but he went to Newfoundland, seeking a bluff. (Laughter.) He found it. Then, turning his eyes eastward and southward, the next Anglo-American promontory upon which his eager and anxious gaze fixed was in the vicinity of Boston, but, to his intense disappointment, he found that it was occupied and pre-occupied and that the golfers of Boston were teeing off from Bunker Hill. (Laughter.)

During this evening he has received word from Cape Cod that the Government is willing that he should use that as a coaling station. (Renewed laughter.) He had already had extended to him the genuine and fervent hospitality of our distinguished past President, Alexander Graham Bell, who said "Here is my property at Cape Breton, come and own it for yourself." But southward still was his cry, until he reached New York City, having heard that within this bailiwick and enjoying the freedom of the city, which has been extended to him by our Mayor, he could find a place, not far from us, where perhaps exist the steepest bluffs to be found along the Atlantic coast, to which he may now have the reversion, and which in his honor we will name *Mar*coni Island. (Laughter and Applause.) Now, fellow members, had this been an American addressing an English audience, I should have said you were rather slow.

Prof. Elihu Thomson is not only one of our most distinguished Past Presidents, but, you will agree with me, one of the most distinguished electrical engineers this country has ever produced (Applause), and when at our brief bidding he comes as others have come, hundreds of miles to join with us in our greetings and acclamation to the guest of honor this evening, we can all feel deeply pleased and gratified at the earnestness he has shown in joining with us in this celebration. I have now the greatest pleasure in calling upon Prof. Thomson.

PROF. ELIHU THOMSON:—Mr. President, Ladies and Gentlemen: I am sure your toastmaster has done more than justice to myself; in fact, he has so treated me that my modesty almost

compels me to sit down and say nothing. Inasmuch as I have made this long journey from the hub of the universe to one of the outlying stations, I surely shall try to do my best on an occasion of this kind.

We are present here this evening to do honor to a gentleman who does us honor in coming here and presenting to us in the simple, straightforward manner in which he has spoken, the results of his great work. I think I can speak for you all in saying that we are intensely gratified that he has been able to do this for us. Our feeling of gratitude is almost beyond our powers of expression. We realize perfectly the many difficulties which he has had to contend with. We know that pioneer work in any field is not by any means easy. It is always hard work. It is not easy to set going these forces and get valuable results. His last achievement reminds me of a school boy companion whom I lost sight of for a very short time. He was one of the smallest fellows in the class. When I next saw him he was about six feet tall. Such was my idea of wireless telegraphy a short time since. It was a small thing but had possibilities of growth. But all of a sudden it jumps to a height that we did not dream possible. In other words, it jumps across the Atlantic ocean. Marconi went quietly to work and laid his plans. and, without saying a word to anybody, got ready to make this supreme test, and when he made it, succeeded in doing what he might be expected to succeed in doing, provided, of course, he had everything at his command conducive to the result—in other words, command of enough electrical energy and a confidence in the working of his apparatus, which comes only from entire familiarity, and as one may say, from living with it.

There was really no need of the trans-Atlantic feat of Signor Marconi to convince us that he was doing a great work, but when we heard of that, we certainly felt that he had done far more than we ever expected he would do in so short a time. I well remember when a few weeks ago the announcement was made in the newspapers. I first heard of it through a reporter's call over the telephone, which was, " What do you think of Marconi? " I replied, " Why, what has he done? I haven't read the papers to-day." " Why, he claims that he has sent messages across the Atlantic." I answered, " If he says he has done that, he probably has done it." (Applause.) Signor Marconi's method of work has been such as to command the admiration of all engineers, and of all scientific men, because it has been scientific from the first, and at the same time he has never lost sight of the commercial aspect of the subject. The whole field of wireless telegraphy is one full of most interesting scientific problems, and were there not the slightest probability of a commercial outcome there would be a grand edifice of scientific work remaining. But, on the other hand, there is indeed the greatest promise of commercial results, and Marconi has even taken you into his confidence to only a certain degree here to-night. I have no doubt he would

be able to say a great deal more of what he can promise in times to come if he wished to do so. He is not yet sure of some things that he knows pretty well will come to pass, but he is modest enough to stand back and say "I won't say anything about those now." He has given us in private a few suggestions of what he has been doing, and what he expects to do.

The man who succeeds in this world is one whose ardor is not damped by obstacles, one who makes obstacles stepping stones. In my philosophy of life, I find that there are two classes of people: Some meet an obstacle and say " I cannot get over that "; others say " I must get over that," and, having got over it, they open up a wide field of useful art or something of the kind; they make an advance; their ardor is not damped by obstacles in the way. The successful men are those who, instead of being set back by an obstacle, say " This is a stimulus to do better, to go farther, to progress to a degree which I at first did not think was possible."

The modern age, the age in which we live, is distinguished from the ages preceding by the quickness with which scientific work and discovery, however recondite they may be, however theoretical they may seem at the start, are soon put to practical use whenever they can be used. Instance, for example, the Roentgen ray, which was no sooner known as a scientific discovery than surgeons began using it. We also find that it is being used in the diagnosis of disease, such as tuberculosis of the lungs and in pneumonia. Further than that, these rays have another quality; they are used in actually killing bacteria, curing skin diseases, and even, to a certain extent, cancerous growths upon the skin. All these uses of the Roentgen rays have been discovered and developed within a very short time.

Hertz waves were discovered about fifteen years ago. They were simply a confirmation of the electro-magnetic theory of light as enunciated by Maxwell, oscillations taking place in a discharging circuit, or oscillations produced in any way in a circuit, and a radiation of energy from that circuit taking place in all directions in the form of Hertz waves in the ether. These were found and recognized, at varying distances away, by suitably attuned receivers. And upon this basis it is that Marconi has built. It was long ago pointed out by Henry that condensers, Leyden jars, in discharging produced oscillations. Clerk Maxwell dealt mathematically with the same problem. Hertz however, by experimental investigation proved the reality of these things which had been mathematically treated of before. Wireless telegraphy of to-day is built upon the foundation laid by Hertz.

We have in the electrical gamut all sorts and kinds of oscillations. The Roentgen ray may be said to top the scale with its thousands of millions of millions of oscillations per second. The ordinary luminous rays come further down in the scale; the violet topping the rate in the ordinary spectrum, down to the

red, where we find the pitch much lower. Below that we find the invisible heat rays, and further down still the very wide range of pitch covered by the Hertz waves or oscillations, as they are termed, the same in their nature as light waves, but invisible, carrying energy and capable of being produced over a very wide range of what is called frequency. Marconi tells us that he has used a frequency of something like 800,000, or close to a million per second, which is, of course, many millions of times below the rate which would give us anything in the nature of light. In our ordinary alternating currents, however, we have only a very few waves per second. We have, then, the whole gamut from a few per second up to the most extreme possible rate which, perhaps, is capable of being generated by the atonic charges of matter in vibration.

I did not mean to take any great time to dwell upon these matters. It is certainly a surprise to me that the Anglo-American Company should attempt to hold back Marconi's experiments and to claim a monopoly not, as Signor Marconi says, of the earth and the air, but of the ether. What is this ether of which we talk so glibly? We do not know. It is apparently the substratum of everything. It is the thing of all things about which we probably know least, but which we know most certainly exists. It is something which we know must exist in space, but we know very little about its actual properties. And still the whole art of electrical engineering, the whole science of electricity, is built upon the interaction between the ether and ordinary matter, as we call it. In other words, we have in electrical work the science of the ether as affected by ordinary matter—the matter in ether. We cannot get along without matter. We cannot get along without ether. But whether matter itself is a form of ether—some modification which has been brought about in ether—is a question which the science of the future has to answer.

Wireless telegraphy will do away with many things which we have hitherto counted as necessities. We will have no dead cables or wires. The ether is always alive, communication always open. We will never need to think of open circuits in that medium. We will never need to think of a new investment in cables. When a man sends to you, at the end of a telegram wanting you to do something which you probably do not want to do particularly, "Wire answer," it may in the future take the form of "Please answer coherently." (Laughter and applause.)

THE TOASTMASTER.—Surely, ladies and gentlemen, this evening, if never before, the fact has been demonstrated that electricity has no nationality. Ralph Waldo Emerson, when visiting England a great many years ago, being impressed with the energy which he found on every hand in that little island, said that he regarded steam as half an Englishman. As we Americans look around us and contemplate the work which has been done in this country during the last forty or fifty years bearing the illustrious names of Joseph Henry, of Morse, of Alexander

Graham Bell, of Brush, of Edison, of Sprague, and many another of our fellow-members, why, we are half inclined to exclaim that electricity is altogether a Yankee. But even as that thought rises in our minds, there loom up the great classic shades of Faraday, the Englishman; Ampère, the Frenchman; Ohm, the German; and Jacobi, the Russian, to say nothing of great Italians—and we come back to the proposition which I have just enunciated, that electricity knows no nationality in its scope and in its achievement, as we have seen demonstrated and illustrated this evening.

And in calling upon the next and closing speaker of the evening, this fact is brought once more forcibly to our attention. It was once said by a great Slav, one of the finest metaphysicians and mathematicians the world has ever known, that, as for his countrymen, they had never been able to invent even a mouse-trap that anybody could sell.

It has fallen to the lot of one member of the Slavic race to be most successful in harnessing the great energies and forces of Niagara, and I would like to put it to the great telephone company in this country what it thinks of that mouse-trap theorem as applied to Dr. Michael I. Pupin. (Applause.) It is at least a singular and happy coincidence that on my right and on my left—both from the far eastern corner of Europe—are the two men who within the last year have most concentrated the scientific and electrical engineering attention of the world in the work which they have done in facilitating the communication of intelligence. I refer to Marconi and Pupin. (Applause.) Surely, they are assisting in that assimilation and blending of the nations which is now going on at a faster rate than ever before, and which perhaps was unhappily illustrated in a more barbaric fashion in the experience of the Chinese consul before he came to our city, being then stationed in Samoa with one clerk. It happened that a cannibalistic banquet intervened in which two chiefs participated, as the result of which the consul alone left the island. His next post of duty was in New York City, and in establishing his telephonic connection he requested Mr. Bethell to make his number "Two ate one John." (Prolonged laughter.)

Aside from the fact that Dr. Pupin is a distinguished member of the Slavic race, he has another call upon our gratitude, and that is as being a representative here to-night, with his fellow-professor, F. B. Crocker, of Columbia University, which upon its high hill in this city stands a bright beacon and center of illumination and culture and civilization and purity in political and social administration. More than that, we are indebted to one of its graduates and one of our fellow-members, who I am sorry not to see here to-night, Dr. Schuyler S. Wheeler, for one of the most munificent donations that a scientific body has ever received in this country from one of its members, in the purchase of the Latimer Clark Library and its gift to this INSTITUTE. (Applause). That gift was immediately seconded by another gift

from Mr. Andrew Carnegie, who, finding that somebody else besides himself had the library habit, immediately equalled Dr. Wheeler's gift, so that the library could be carried on and sustained.

And now, gentlemen, with that library, the equal of which does not exist in this world, we are looking around for a building, and when Signor Marconi has signalled across the Pacific ocean, we hope to entertain him in the tallest building the world has ever seen, because, gentlemen, you know that in a library building there is no limit to the number of stories. We have understood that possibly from the wealth which has been accumulated in telephonic circles, and even by our friend, Dr. Pupin, we may eventually hope to attain our fondest ambitions in that direction. I have now the greatest pleasure in introducing to you our distinguished fellow-member, Dr. Pupin.

DR. MICHAEL I. PUPIN:—Members of the INSTITUTE and guests. A few days ago our Committee on Papers was so kind as to invite me to be present here this evening as a guest and to make a few remarks on a subject with which the work of our distinguished guest of honor, Signor Marconi, has been identified. I have followed Signor Marconi's work with much respectful attention during the last six years. His experiments aroused my scientific interest and curiosity; his struggles excited my sympathy, and his success was always a source of the greatest gratification to me, as it is to all of you who are delighted in seeing true merit rewarded. (Applause.)

I shall, therefore, be very happy indeed if, by the few remarks which I have to offer this evening, I may in any way contribute to a clear understanding of the aims of our distinguished guest and of the means by which he hopes to accomplish his task.

One cannot very well discuss any topic connected with Signor Marconi's work without plunging headlong into the bottomless sea of electrical waves, and then he has to struggle hard to keep his head above the etheral fluid. He has, indeed, to be a very expert swimmer. He must be a physicist of ingenuity and rare skill; he must be a mathematician of exceptional training, and above all, he must be an engineer of sound judgment.

Now, I must say that I cannot lay a just claim to any one of these most exceptional qualities. You can see, therefore, that my position this evening is rather a difficult one. It is true that I do teach future electrical engineers in electro-mechanics, a subject which implies a fair knowledge of physics, electrical engineering and mathematics. I say, a fair knowledge only, and I mean that the amount of knowledge required is really a great deal less than people suppose. It would not be a wise policy for me to say this within hearing distance of our University, of course, because a professor's salary, small as it is, often depends on how easily he and his subject can be replaced (Laughter); but here in this distinguished assemblage, where I see the faces of some of the most distinguished engineers in the country,

I must be frank if I am to expect leniency. It is true, also, that electro-mechanics has a great deal to do with electrical waves. Perhaps on that account I happened to take a particular interest in this field of work.

Now this subject of electrical waves has three sides: the purely mathematical side; the physical side; and, finally, the engineering side. It is on that account, perhaps, that those men who engage in the research of this particular subject are more or less pioneers, because the subject belongs to three different departments of general physics, without belonging to any one in particular. It is in the borderland, and that offers some advantages. If one working in the field of electrical waves happened to find something which after much argument his intimate friends admit to possess some novelty, then he goes to the American Mathematical Society and reads a paper on the mathematical side of his investigation; they say "Why, for a physicist he is a pretty good mathematician." Then he goes to the American Physical Society and gives an account of the physical side of his work, and they will generously admit that for an electrical engineer he is a pretty good physicist. Finally, he goes to the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS and gives them an account of the engineering side of his work and they will tell him that for a pure mathematician his engineering judgment is not at all bad. (Laughter.) In that way one gets on. It reminds me of a story which I heard Sir Robert Ball, the English astronomer, relate the other day in a lecture. He said that many years ago there was a famous professor at the University of Cambridge. He was famous, not because the people at Cambridge thought he was, but because the people of Continental Europe made him famous, and it happened in this way. He was a professor of astronomy and of geology. Whenever he called on his distinguished friends on the Continent he took with him two sets of visiting cards. On one set he was Professor of Geology and on the other set he was Professor of Astronomy. Whenever he called on a geologist he sent up the card on which his title was Professor of Astronomy and when he called on an astronomer he sent up his card with the title of Professor of Geology. In that way he became very famous as a man of broad learning. So it is with a man who works in electrical waves. He gains some fame, and he does not himself know how. As I said, because the subject of electrical waves is on the borderland, every man who works on the borderland is a pioneer, and the world, of course, admires the pioneer. It is, perhaps, on that account, also, that there is no particular class of men making the study of electrical waves a particular work of their own; that the subject of electrical waves is perhaps less understood than any other study in physics and electrical engineering. You have heard people say that Mr. Marconi's system is nothing more or less than Hertz's system; that there are Hertzian waves, and that they are transmitted through the ether. Another man

will say that they are transmitted through the earth. Another will say thay are transmitted through the water. One man said to me the other day, "Why, anybody can do what Marconi did. One end of the Anglo-American cable was near Cornwall, and the other near Newfoundland, and Marconi sent his signal through the cable, and it is no wonder that the Anglo-American Company is kicking. He is using the cable for transmitting his signals. He is going to Cape Cod next. Another cable lands near there. He always goes wherever there is a cable terminal." (Laughter.)

Anybody who understands anything about the theory of electrical waves knows that to transmit oscillations of this enormous frequency through a cable would be a much more wonderful achievement than to transmit them through the ether. Now, I shall devote a few minutes, only, to some explanations—you see, teaching is my business and I must always explain, so if I am somewhat didactic you will understand that it has become a habit of mine; I cannot help it. I shall explain the difference, in as few words as I can, between the Hertzian waves, the telephonic or the Bell waves, and the Marconi waves. Several years ago I read an article written by that most distinguished mathematician, Oliver Heaviside. It was a criticism of another article written by another most distinguished physicist—the late Prof. Von Helmholtz, of the University of Berlin—and it dealt with the subject of the electromagnetic theory of light. Heaviside found fault with it, saying that it did not satisfy the conditions of a telegraphic circuit. Now, many of you will say: What in the name of common sense has a telegraphic circuit to do with the electro-magnetic theory of light? That is exactly what I said at that time. I did not understand it. Very often we do not understand Heaviside for the time being, but in about ten years or so his meaning suddenly dawns upon us. So one day last summer when it rained all day long, and it was impossible to go out and play golf or call upon one's idle friends, I was forced to stay home and pass my time in idle speculation; and, naturally enough, I speculated about electrical waves. It happened that a short time before that I spent a very pleasant evening with Signor Marconi under this very roof, and our conversation somehow or other drifted in the direction of electrical waves; some bits of this conversation still stuck in my brain, and the principal subject of my speculation on that day was concerning the conversation I had with our distinguished guest. I said to myself, now, here are Hertzian waves and Marconi waves and Prof. Bell's waves, and all other kinds of waves. What is the use of calling these waves by so many different names? I am perfectly sure, I said to myself, that Prof. Hertz, if he were alive would not care to hear people call any particular set of waves by his name, nor am I aware that Signor Marconi is anxious to label another set of waves as Marconi waves, nor that Prof. Bell claims all telephonic waves, nor that every telegraph or power transmission

station working with alternating currents would care to label every one of its waves. It would not be just and it would not be practicable. I said to myself, there are no different breeds of waves; they are all one and the same thing. Well, said I to myself, if they are all one and the same thing, is there possibly any convenient method of classifying them? Well, there is. The difference between waves consists in the manner, in the combination of an apparatus, by which you produce them, and the purpose for which you wish to employ them.

Now, I said a little while ago, that the subject of electrical waves has a mathematical, a physical and an engineering side. Speaking from a purely mathematical and physical standpoint, there is no difference between electrical waves, absolutely none. But speaking from an engineering point of view, there is every difference between them. How absurd it is, then, to hear every now and then people say, "Why, years ago I stuck a wire here and I stuck a wire there and I actually transmitted signals across my back yard, using an open circuit; my work is just as good as Marconi's; there is no difference between us." Why, you might just as well say that there is no difference between the Brooklyn Bridge and the bridge which Julius Cæsar describes in his book "De Bello Gallico." There is every difference, the difference consisting chiefly in the construction of the apparatus which you employ. I also heard a man say, "Years ago I thought of transmitting wireless signals by the wobbling of the charge of the earth." Well, any one of us can think of schemes like that; any one of us who has had any experience in inventing can think of schemes like that as fast as you can write them down, for anybody knows you can transmit electrical waves to any distance, that is, mathematically and physically perhaps. But how about the engineering side of it? I said to this man, "Give me an engineering specification of your apparatus by means of which you intend to wobble the charge of the earth, and then I will believe you; not before."

Now this is what Signor Marconi has done. He has written out a specification for setting up apparatus and wobbling the charge of the earth and transmitting the signals between wires. (Applause). We have here, then, the idea and the engineering fact. The idea is all right as far as it goes, but without the engineering specification it amounts to nothing as far as the possibility of obtaining desirable results is concerned.

Well, now, what are the Marconi waves and the Marconi apparatus? In fact, I will take the first question back. I ask what is the Marconi apparatus, because if you know what the telephone waves are and the telegraph waves and the Hertzian waves, you know what the Marconi waves are. They are exactly the same thing. What we want to know is, what is the Marconi apparatus, and does it differ or does it not differ, from other apparatus, employed before, for the production of electrical waves? Now, on that rainy summer day when I sat speculating,

I came to this conclusion: All apparatus for the production of electrical waves and the reception of electrical waves by the law of evolution or the law of continuity, may be deduced from two sets of telegraphic circuits. That is what Heaviside meant when he said that Helmholtz's theory did not satisfy the conditions of a telegraph circuit.

I shall now show you how we may take a telegraph circuit and by a continuous change evolve from it the Hertzian apparatus for the production of electrical waves. I do not think that any subject dealing with engineering can be properly presented un-

FIG. 1.

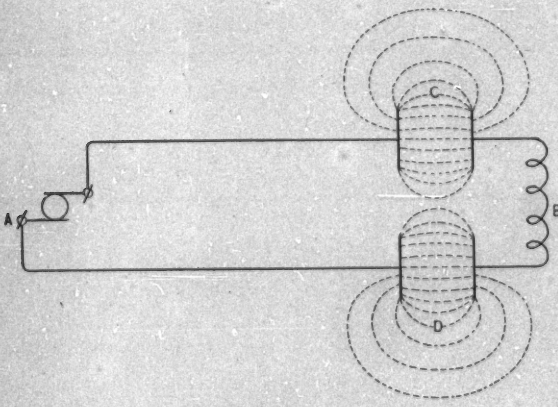


FIG. 2.

less you have either a blackboard or a few diagrams, and so I venture to offer you a real novelty, an after-dinner speech illustrated by diagrams. If, in spite of this effort on my part, you fail to understand my jokes, it will not be my fault. Here is diagram Fig. 1:

This may be called a typical telegraph circuit. A is the sending generator and B is the receiving apparatus; for a specific

reason I have introduced two condensers, C and D. If the circuit is long, say a mile, and the condensers are large, we can use a transmitting generator of low frequency. In the next place, let us increase the frequency by giving the generator a higher speed. Now we may diminish the size of our condensers. The size of the condensers may be diminished by putting the plates further apart as shown in Fig. 2. Here I want to call your attention to the fact that the electro-static lines of force begin to bulge out. In the first case shown in Fig. 1, the lines of electro-static force were practically all straight from plate to plate, because there was no stray external field. But in the second case there is, that is to say, the condenser begins to be more sympathetic

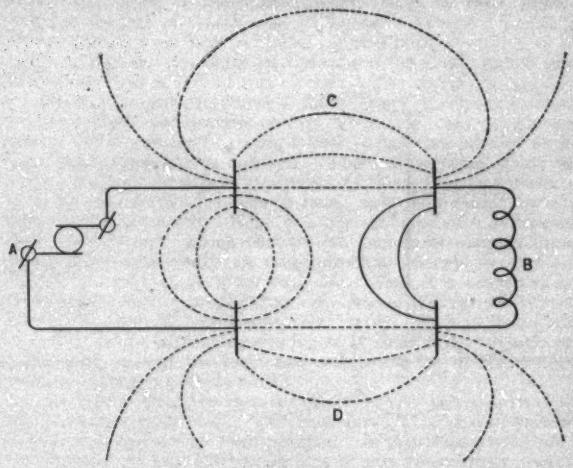


FIG. 3.

and to communicate with the rest of the world, throwing out its feelers in the shape of electro-static lines of force. Now, increase the frequency of the alternator still further and, of course, as everybody knows, we may still further diminish the capacity of our condensers, which we do by separating the plates C and D and placing them at a considerably longer distance apart, as shown in Fig. 3. The fact to which I wish to call your particular attention is that the electro-static field of force is bulging out still more; it throws out its feelers more and more and can affect bodies on the outside. We say that the condensers and therefore the total arrangement begins to have more and more radiating power. Radiation is simply the capacity of a system to

communicate energy to other bodies outside of the system. You see, then, that as the frequency increases, the condenser plates may be taken further apart and the system begins to have larger

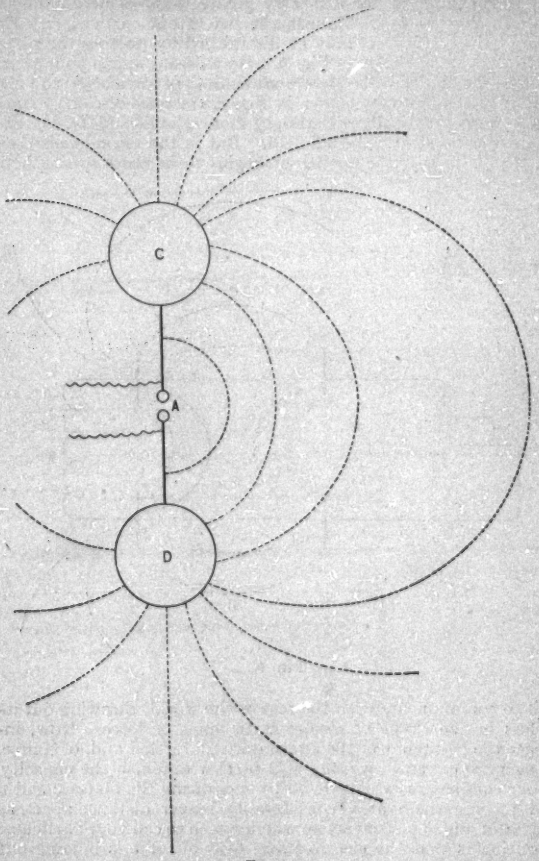


FIG. 4.

and larger capacity for radiating power, and to affect bodies outside of the electrical circuit under consideration.

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Suppose, now, that we want to work at a still higher frequency, having in the last case reached a frequency of ten thousand periods per second. From this point on, sound engineering judgment tells us—and, mind you, I said that in dealing with electrical waves in their practical applications you have to be not only a mathematician and a physicist, but you must be also an engineer, that is to say, you must have sound practical judgment—from that point on, sound engineering judgment tells us: You have reached the limit of speed of the machine. The periphical speed is 6,000 feet per minute. Stop. You must use, now, something else. Our knowledge of physics tells us to use an artifice which Joseph Henry employed in 1842 and Feddersen again in 1858, and finally Hertz in 1887, with the brilliant success of which you all know. We use a spark gap. The condensers are now replaced by two balls, C and D, as indicated in Fig. 4. In place of the generator is the spark gap A. This is all that is left of our circuit. The receiving end of our circuit may be put anywhere. After every spark discharge at A we have rapid oscillations of any frequency that we choose to select. It is just like striking a bell; after each stroke we have a sonorous sounding of the bell. The bell becomes silent again after it has sent forth into all directions the energy communicated to it by the stroke. Observe here, now, the radiation of the lines of electric force: Here is a perfect type of a sympathetic circuit—a circuit which throws its feelers of electric force in every direction, ready to communicate energy to any other circuit or body at its own expense. This is a circuit of large radiating power. But for that very reason it gives off its energy at a rapid rate; it is not sonorous, but so lavish in its radiating power as to be almost aperiodic. It does not continue to vibrate, but during its very first vibration its entire energy is thrown upon the outside world.

Now this is the Hertzian oscillator. You can transmit wireless messages with that. But how far? If you transmit them a mile you are a fine manipulator. A gentleman told me the other day "At our University one of our young men years ago transmitted wireless messages over a mile, the same as Mr. Marconi." I said, "That is very nice for the young man, but how did he do it?" "He used a Hertzian oscillator," he replied. I said "That is a very different story. If he has transmitted a mile he has probably done a very good thing; but he could not do it any farther than that to-day, even if he had kept on trying from that day to this, whereas Mr. Marconi gets easily over a hundred miles." You see, this was an educated man and he understood the subject fairly well; nevertheless, he actually believed that his young man had done the same thing that Mr. Marconi is doing to-day, only his young man was too modest to announce his great feat to the world, and too unselfish to form a stock company.

This, then, is the apparatus, by means of which Hertz produced

electrical waves. There was nothing very novel in that apparatus at the time when Hertz first employed it, and Hertz never claimed that there was anything novel in it, and if he had, there is no doubt that Prof. Lodge for one would have called him to order.

What, then, did he claim? All these oscillations can be and were predicted by Prof. Thomson, now Lord Kelvin, on the basis of the old theory, a theory of a hundred years ago, the theory which was completely worked out in the days of Ampère and Faraday. But there was one thing that could not be predicted by the old theory, and that is, that if you proceed from the oscillator in a certain direction you will get to a point where you get no induction, and then to a point where there is strong induction, and then again to another point where there is no induction, and thus he proved the existence of electrical waves in the ether. Hertz proved that electrical energy traveled from the oscillator with a finite velocity equal to the velocity of light. He did not claim the apparatus nor the waves. He claimed nothing except to have proved by experiment that electrical energy radiated from this apparatus with the velocity of light. That is the reason I said that if he were living to-day he would object that any waves should be called the Hertzian waves They are simply electrical waves.

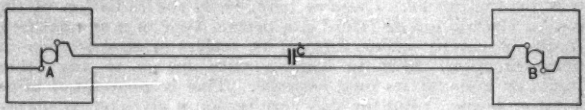

FIG. 5.

An engineer of sound judgment will tell you that from a mathematical and physical point of view you can transmit electrical waves to any distance, but he will also tell you that practically you cannot transmit them over more than a mile, if you employ the arrangement which Hertz employed.

This Hertzian arrangement was entirely different from the system known as the Marconi arrangement, and to prove it I shall now perform another transformation trick. I shall now evolve the Marconi system from the telegraph circuit of the second type. I told you that all apparatus for generating electric waves may be evolved from one of two types of telegraph circuit. The first type that I have just shown you is the land circuit; the second is the submarine type, the so-called cable. For this purpose I have borrowed a cable, not from the Anglo-American Company, but from the Commercial Cable Company. Here in Fig. 5 is a diagram of what may be called the second type of telegraph circuit, that is, a cable. Say this end at A is the transmitting apparatus at Cornwall, and this end at B is the receiving apparatus in Newfoundland. The line in the middle connecting A to B is the conducting core of the cable or the copper conductor. The terminal

squares are the stations, and the tubular arrangement between them is the sheathing which protects the copper conductor. I have also put a condenser, c, in the middle. (Laughter.) I understand that is not the usual practice, but still it could be done. I violate no scientific principle in doing that, and I have introduced it for a definite purpose, which will be apparent presently. Now, to transmit signals over this cable we all know, and Mr. Marconi will not contradict us, that we have to transmit very slowly on account of certain limitations. Therefore, our alternator at A has to work at very low speed. Suppose, now, that we wanted to increase the speed of the transmitting alterna-

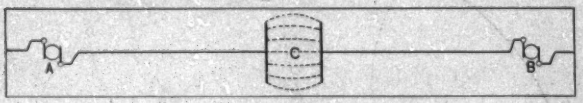

FIG. 6.

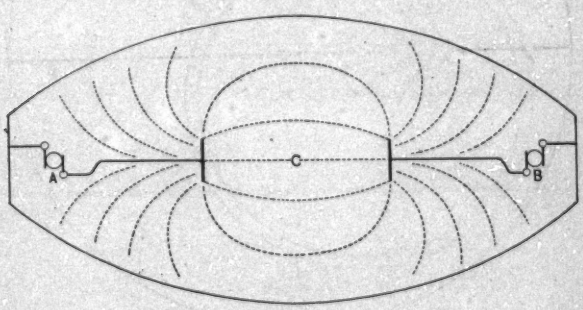

FIG. 7.

tor, thereby increasing the frequency of the alternating current which we employ, we would have to increase the cross-section of this sheathing so as to diminish the capacity; and we can also then diminish the capacity of the condenser c, without any loss or inconvenience, because the higher the frequency the smaller can be the capacity of condenser c.

Now, the second cable (Fig. 6), is a cable which has a higher speed. It is a cable of a larger cross-section of sheathing. I do not pretend that this is a practicable cable, but for the sake of the scientific demonstration it will do. The point to which I wish to call your attention is that, as the size of this condenser c is diminished, the lines of electro-static force, indicated by the

dotted lines between the plates, begin to bulge out as if they were anxious to communicate their energy to the surrounding bodies.

Now, suppose we want to raise the speed of our transmitting apparatus, we would then have to increase the cross-section of our sheathing again, and we can then still further increase the distance between the condenser plates. Then we have this state of affairs shown in Fig. 7. The electro-static lines of force between the condenser plates bulge out very strongly. There is a very pronounced tendency on the part of the condenser to com-

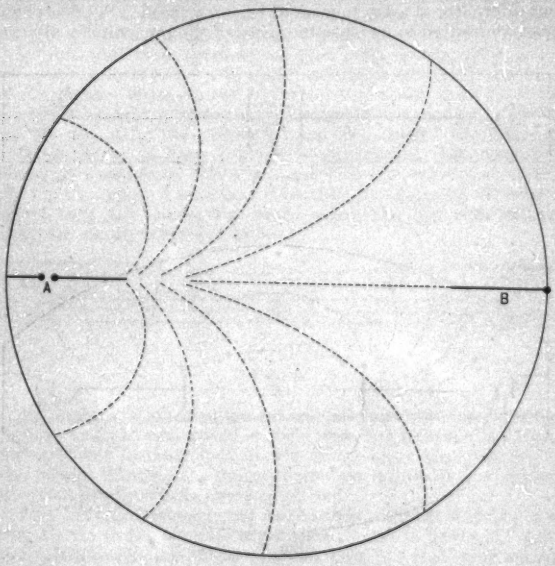

FIG. 8.

municate energy to the surrounding conducting bodies or to the ether.

With a cable like that we could use very high frequency. But suppose we wanted to use still higher frequency, then we would have to increase the sheathing very much, using the spark-gap, and then we would have this state of affairs shown in Fig. 8. Mind you, the sheathing now will be very thin indeed, and we can afford to have it as thin as we please because these high frequency currents are transmitted through a very thin layer near the surface of the conductor. So whether we have a thin or a thick conductor does not make any difference. The original sheathing will suffice to enclose as much space as we please.

There is nothing to prevent us from making this sphere as large as the earth.

Here is a system of wireless telegraphy that would be even better than Marconi's system. It would communicate most of its energy here from the transmitting apparatus A to the receiving apparatus at B. You see, the condenser and cable core have almost entirely disappeared; the capacity of the condenser C is replaced by the capacity between the terminal wires at A and B and the surrounding sheathing. But of course an arrangement like that, as big as the earth, would not do. So, although the scheme is a very nice one, mathematically, mind you, and

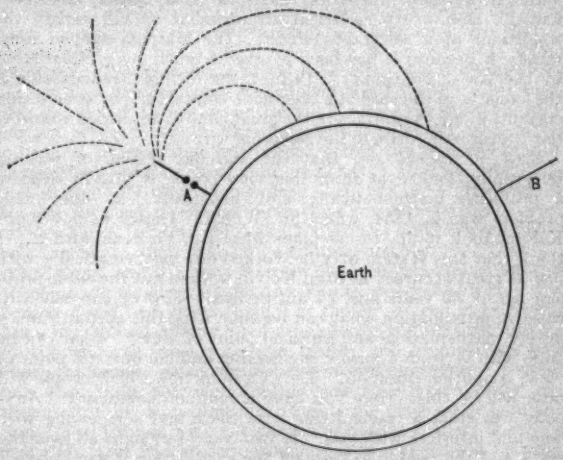

FIG. 9.

physically, it would not do from a purely engineering point of view. But it serves a very good purpose. It enables a mathematician to calculate in an exact and complete manner how the waves proceeding from A are going to be transmitted to B. You get a most beautiful result. It is a pity that the arrangement is not satisfactory from an engineering point of view.

But I said that a man dealing with electrical waves has to be not only a mathematician and engineer, but also a physicist. Now a physicist would say this: Why not make a cut here along a meridian of the spherical shell and then turn it inside out, and drop the earth into it. Then we would get this arrangement in Fig. 9. Here is now the sheathing all around the earth. Here is one wire at A, here is the other at B, and that is the Marconi system. (Applause.) It is more than that, because if he had

this thin conductor all over the earth it would stop business and interfere with people. This thin conducting covering is a relic of barbarism, Sig. Marconi will undoubtedly say, reminding people of the cable from which we have just evolved his system. The physicist will tell you that it is unnecessary; the earth is a conductor, and therefore there is no necessity for the conducting sheathing; cut it out; run your transmitting wire, A, right into the earth and also the receiving wire, and you have the Marconi system. Here, then, in a didactic way, is, a complete representation of the Marconi system, and we have evolved it by gradual steps from the second type of the telegraph circuit. The Marconi system, therefore, satisfies Heaviside's condition, namely, that every electrical arrangement should satisfy the conditions of a telegraph circuit. The Marconi system must satisfy it because it has been evolved from it by gradual steps by the law of continuity. In fact, the form of transmission is the same as in the case of a telephone conductor, by conduction currents along the surface of the great conductor, which connects the transmitting wire to the receiving wire.

Now, it follows also that the Marconi system of wireless telegraphy, looked at from this view-point, is just as definite a problem, mathematically and physically, as the cable problem was in 1854, when Sir William Thomson, now Lord Kelvin, took it up, to calculate what can be done with it. I think that this system may be worked out mathematically with just as great accuracy as Lord Kelvin worked out the cable problem nearly 50 years ago. I am perfectly sure we can tell with close approximation what can be done with this system from a purely mathematical and physical point of view. What can be done with it, from a purely engineering and commercial point of view, is another question. The first objection which people will raise will be this: Here you have a common conductor. Anybody can stick a transmitting wire there and a receiving wire here and interfere with you. If you could put signs all over the earth and tell people to keep off the earth, then it would be all right, but you cannot do that. We are not all like the Anglo-American Company, claiming the earth and the sea and the ether. We have to let other people enjoy some rights and privileges. Now Sig. Marconi tells us that by the system of electric resonance and syntony he can overcome this difficulty. If he says so, I am inclined to believe him, if for no other reason. But in scientific work we never believe anything until we see a demonstration of it. I believe that Sig. Marconi has transmitted the famous three dots across the Atlantic, but I must say that I believe him because I know him personally. If I did not know him personally, I would not believe him, because the proof which Signor Marconi has furnished is not sufficiently strong from a purely scientific point of view; but knowing him personally as I do, I believe his statement. Well, what of it? Suppose he has transmitted trans-Atlantic signals. Suppose that the wireless

system of telegraphy enables us to transmit signals across the Atlantic in a satisfactory way, what of it? Is that going to affect the condition of the present cable companies? It may at first, perhaps, if the Marconi system proves to be just as good a system and even a better one than the present cable systems. But it will affect them in the same way that electric lighting affected the gas companies. Gas stock went down at first. To-day it is way up. How did the telephone affect telegraphy? Why, telegraphy stands higher to-day than it did in 1876. Do you suppose the perfection of bicycles and automobiles has affected the price of horses? Why, last spring the prices of horses were higher than at any other time in the history of this country. I myself sold a horse last spring to a dealer for more than I paid for it several years ago. (Laughter.) So that I, for my part, if I had a lot of stock in a cable company, which unfortunately I have not, I would stick to it. I think that every success that Marconi may accomplish will help the cable business, instead of doing the contrary. I think that whatever may happen, whether Signor Marconi succeeds in giving us a better system of transmitting intelligence across the Atlantic or not, of one thing we may be certain, and that is, that we must judge him to-night by what he has done. He has done great things. He has supplied us with a method of communicating between moving ships, between ships and lighthouses and between places between which there was no communication before. That is a grand thing, and if Signor Marconi does not accomplish another thing, he has done enough for any man to be satisfied with. But I think it will be a grand thing if he should succeed in perfecting a system of transmitting intelligence across the Atlantic and the Pacific with the same exactness, facility and promptitude with which the present cable companies transmit messages. It would be a great thing because we would then have a competitor, and there is nothing so powerful in stimulating progress as competition. The trouble with the cable companies, if there is any, is that they have had no serious competitor. There was no progress, in a certain sense, but I should rather say that there was progress, only I think there might have been a great deal more progress, if there had been more competition; if two or three or four different systems had been competing against each other. Let Sig. Marconi perfect his trans-Atlantic system. I wish him success from the bottom of my heart, because I am sure that if he does succeed there will be a cable transmission system in less than ten years that will astonish the world. I am sure, therefore, that every one of us, the cable engineers included, wish Signor Marconi a signal success. (Applause.)

At the conclusion of Dr. Pupin's remarks the toastmaster invited the guests and members to remain for a few moments after the banquet, if they desired, so they might have the opportunity of being presented to Signor Marconi. The privilege was generally accepted and the guest of the evening was the recipient of hearty congratulations from the members present.

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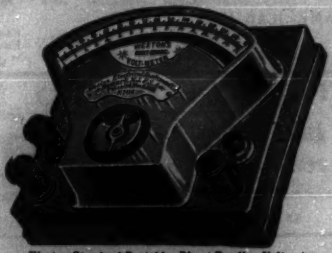

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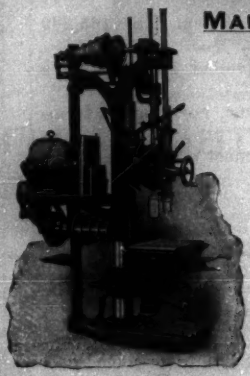

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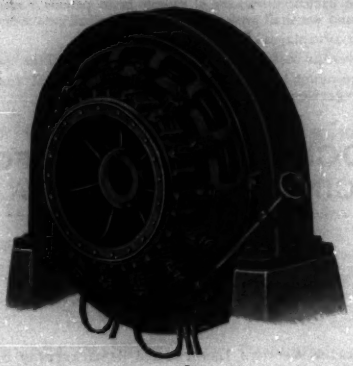

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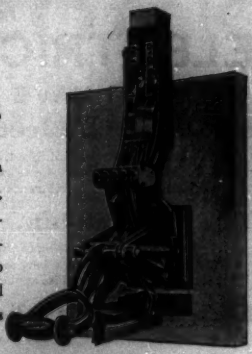

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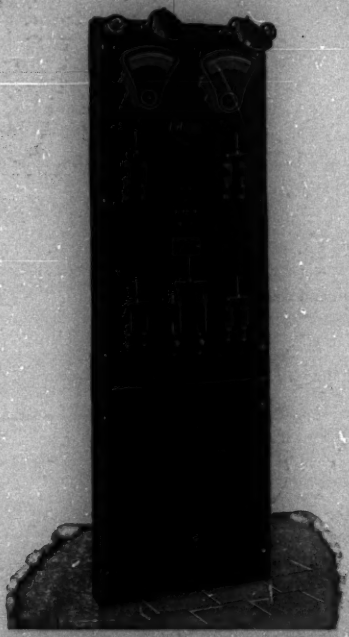

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